Risk Assessment Mitigation Phase

Risk Mitigation Plan

Electric Infrastructure Integrity (Chapter SDG&E-12)

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Executive Summary

The risk of Electric Infrastructure Integrity is the occurrence of a safety, environmental, or reliability incident due to equipment failure. This equipment or asset failure could be caused by conditions including, but not exclusive to: degradation, age, operation outside of design criteria due to unexpected events or field conditions (e.g., force of nature), or an asset that is not constructed with the latest engineering standards. SDG&E's 2015 baseline mitigation plan for Electric Infrastructure Integrity consists of four categories of controls:

1. Premature Overhead Failure
2. Premature Underground Failure
3. Premature Substation Failure
4. System Modernization

These controls focus on safety-related impacts (i.e., Health, Safety, and Environment) per guidance provided by the Commission in Decision 16-08-018, as well as controls and mitigations that may address reliability. SDG&E will continue the 2015 controls in the proposed plan. In addition, SDG&E proposes to expand and add new mitigations to further address the risk of Electric Infrastructure Integrity. Examples of these incremental mitigation activities include:

- A Wire Correction Program, which will effectively replace or protect the assets most prone to failure.
- A 4 kV Modernization program, which aims to continue and accelerate traditional conversions of the 4 kV systems, including substations and both underground and overhead, to 12 kV standards. These upgrades would enable better protection against risks such as wire down events.
- A Switch Maintenance Program for both underground and overhead switches. This program aims to systematically and thoroughly inspect all distribution switches.
- An acceleration of SDG&E's Advanced SCADA Program across all electric distribution systems.

A risk spend efficiency (RSE) was calculated for Electric Infrastructure Integrity. The RSE is a new tool that was developed to attempt to quantify how the proposed mitigations will incrementally reduce risk.

Risk: Electric Infrastructure Integrity

1 Purpose

The purpose of this chapter is to present the mitigation plan of San Diego Gas & Electric Company (SDG&E or Company) for the risk of Electric Infrastructure Integrity. SDG&E considers the Electric Infrastructure Integrity risk to be the occurrence of a safety, environmental, or reliability incident due to equipment failure. This equipment or asset failure could be caused by conditions including, but not exclusive to: degradation, age, operation outside of design criteria due to unexpected events or field conditions (e.g., force of nature), or an asset that is not constructed with the latest engineering standards.

This risk is a product of SDG&E's September 2015 annual risk registry assessment cycle. Any events that occurred after that time were not considered in determining the 2015 risk assessment, in preparation for this Report. Note that while 2015 is used a base year for mitigation planning, risk management has been occurring, successfully, for many years within the Company. SDG&E and Southern California Gas Company (SoCalGas) (collectively, the utilities) take compliance and managing risks seriously, as can be seen by the number of actions taken to mitigate each risk. This is the first time, however, that the utilities have presented a Risk Assessment Mitigation Phase (RAMP) Report, so it is important to consider the data presented in this plan in that context. The baseline mitigations are determined based on the relative expenditures during 2015; however, the utilities do not currently track expenditures in this way, so the baseline amounts are the best effort of each utility to benchmark both capital and operations and maintenance (O&M) costs during that year. The level of precision in process and outcomes is expected to evolve through work with the California Public Utilities Commission (Commission or CPUC) and other stakeholders over the next several General Rate Case (GRC) cycles.

The Commission has ordered that RAMP be focused on safety related risks and mitigating those risks.[1] In many risks, safety and reliability are inherently related and cannot be separated, and the mitigations reflect that fact. Compliance with laws and regulations is also inherently tied to safety and the utilities take those activities very seriously. In all cases, the 2015 baseline mitigations include activities and amounts necessary to comply with the laws in place at that time. Laws rapidly evolve, however, so the RAMP baseline has not taken into account any new laws that have been passed since September 2015. Some proposed mitigations, however, do take into account those new laws.

The purpose of RAMP is not to request funding. Any funding requests will be made in the GRC. The forecasts for mitigation are not for funding purposes, but are rather to provide a range for the future GRC filing. This range will be refined with supporting testimony in the GRC. Although some risks have overlapping costs, the utilities have made efforts to identify those costs.
The risk assessment provided herein addresses both low frequency-high consequence and high frequency-low consequence events. Another potential event associated with Electric Infrastructure Integrity – the inadvertent contact of an energized SDG&E facility by an employee, contractor, or the

[1] Commission Decision (D.) 14-12-025 at p. 31.

public, potentially causing injury – is not covered here, but in the Employee, Contractor and Public Safety risk chapter of this Report. It is important to note that although the consequences of this risk are similar those described in the Public Safety Events – Electric and Employee, Contactor and Public Safety chapters, the drivers and mitigations often differ. While other risk chapters focus on mitigations that address public outreach, education, training, and other internal procedural enhancements, this chapter focuses on infrastructure improvements. This chapter focuses on mitigations that aim to reduce safety risks directly associated with infrastructure failure or mis-operation, limited to equipment owned and operated by SDG&E. Also, this chapter primarily focuses on risks and mitigations outside of the Fire Threat Zone (FTZ). FTZ-related risks and mitigations are covered in the Wildfire Caused by SDG&E Equipment risk chapter of this Report.

Further, SDG&E is addressing the risk drivers of which it is aware. Potential drivers that are unknown to SDG&E are outside the scope of this risk.

2 Background

SDG&E's electric service territory is 4,100 square miles spanning two counties and 25 communities. It covers the southern portion of Orange County to the U.S.-Mexico Border, and San Diego County from the coast to the western borders of Riverside and Imperial Counties. SDG&E's 1.4 million electric consumers comprise predominantly residential customers, along with a smaller number of commercial and industrial customers. Table 1 below provides an overview of SDG&E's electric system.

Table 1: SDG&E Electric Infrastructure Overview

Transmission	Distribution	Substation
Circuits (Tie lines): 500 kV: 6 230 kV: 47 138 kV: 36 69 kV: 155	Circuits: 12 kV: 808 4 kV: 225	Distribution Substations 12 kV: 112 (no 4 kV) 4 kV (step downs and substations): 195
Overhead Miles: 1,830	Overhead Miles: 6,523	Transmission Substations: 26
Underground Miles: 136	Underground Miles: 10,464	

SDG&E aims to build and maintain a safe and reliable electric infrastructure. To do so, SDG&E employs both conventional and innovative approaches to engineering, designing, constructing, maintaining, and operating its electric infrastructure. The Company creates and maintains construction standards and practices that help to maintain safe operations for electrical workers and the public.

These are challenging tasks given the varying terrain, weather patterns, aging infrastructure, continually and changing load patterns, and the resulting impacts to the safety and reliability of electric infrastructure, across the service territory.

SDG&E is an industry leader in the development of innovative engineering, construction, and operational techniques, having experienced a variety of operational challenges over the years. SDG&E invests in the continual improvement of electric transmission, substation, and distribution infrastructure, as well as in technology to safely monitor and control those assets. SDG&E routinely collaborates with several manufacturers, consultants, and various consortiums of utilities to recognize and continually pursue best practices for the purpose of enhancing employee and public safety.

These investments and practices have contributed, in large part, to SDG&E's maintenance of a consistent trend of industry-leading reliability indices (e.g., Sustained Average Interruption Duration Index, commonly known as SAIDI). These achievements are a result of implementing long-term infrastructure improvements and responding to unplanned outages with urgency. Despite these successful efforts, not all electric reliability risks can be fully mitigated and, therefore some residual risks will remain.

3 Risk Information

As stated in the testimony of Jorge M. DaSilva in the Safety Model Assessment Proceeding (S-MAP) Application (A.) 15-05-002, "SDG&E is moving towards a more structured approach to classifying risks and mitigations through the development of its new risk taxonomy. The purpose of the risk taxonomy is to define a rational, logical and common framework that can be used to understand analyze and categorize risks."[2] The Enterprise Risk Management (ERM) process and lexicon that SDG&E has put in place was built on the internationally-accepted IS0 31000 risk management standard. In the application and evolution of this process, the Company is committed to increasing the use of quantification within its evaluation and prioritization of risks.[3] This includes identifying leading indicators of risk. Sections 3 – 8 of this plan describe the key outputs of the ERM process and resultant risk mitigations.

In accordance with the ERM process, this section describes the risk classification, possible drivers and potential consequences of the Electric Infrastructure Integrity risk.

3.1 Risk Classification

Consistent with the taxonomy presented by SDG&E and SoCalGas in A.15-05-002, SDG&E classifies this risk as an electric, operational risk, associated with transmission, distribution and substation assets, as shown in Table 2.

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[2] A.15-05-002, filed May 1, 2015, at p. JMD-7.
[3] Testimony of Diana Day, Risk Management and Policy (SDG&E-02), submitted on November 14, 2014 in A.14-11-003.

Table 2: Risk Classification per Taxonomy

Risk Type	Asset/Function Category	Asset/Function Type
OPERATIONAL	ELECTRIC	TRANSMISSION/DISTRIBUTION/SUBSTATION

3.2 Potential Drivers[4]

When performing the risk assessment for Electric Infrastructure Integrity subject matter experts identified potential indicators of risk, referred to as drivers. These include, but are not limited to:

- **In-service equipment has passed its useful life, becomes obsolete, or does not operate in accordance with modern safety standards**:

  Electric assets are usually in service for several decades, and, possibly for several years beyond the book life of the asset. Based on an assessment of age, one of the most common key indicators of failure, such assets are more prone to failure. These assets can also be considered obsolete when new safety, construction, and operational standards have been established in the industry or within the Company.

- **In-service equipment overloaded beyond specifications**:

  Electric assets are designed and constructed per SDG&E standards and in accordance with CPUC General Orders and other local or national requirements. Assets often are designed and constructed to exceed the requirements set forth by these standards; however, field conditions, such as excessive forces exerted on poles due to acute natural forces (e.g., high winds), may stress the infrastructure and cause failures.

- **In-service equipment failing prematurely**:

  SDG&E's electric assets such as underground cables, substation transformers, and overhead connectors are supplied by various manufacturers. These assets undergo routine quality testing from their respective manufacturers and operate within their design criteria; however, it is reasonable to expect some subsets to fail over time, under conditions near the upper limits of their ratings, or for reasons unknown to SDG&E.

- **In-service equipment designed to protect other assets failing to operate as designed**:

  Due to their sensitive nature, protective relaying devices, along with their associated telecommunication systems (e.g., Energy Management System [EMS], Supervisory Control and Data Acquisition [SCADA]), can be expected to fail periodically. These failures may cause the assets they are designed to protect to experience more damage or potentially fail prematurely

[4] An indication that a risk could occur. It does not reflect actual or threatened conditions.

under faulted conditions. Relays themselves also may fail prematurely, potentially causing adverse impacts to reliability and safety.

- **In-service equipment failing with lack of or delayed utility awareness**:

  Protective relaying devices and their associated telecommunication systems are designed to provide utility operators with real-time insights regarding the state of electric assets, including which assets pose risks to electric workers and the public. Failure of these systems may cause prolonged or undetected risk exposure to the public.

- **In-service equipment failing in excessive volumes:**

  Although it is reasonable to expect some subsets of in-service electric assets to fail, acute weather events or environmental conditions may pose added risks to SDG&E's operations. In particular, storm events may lead to large volumes of failures that extend the normal outage response time, due to limited resources to assess and mitigate damage, and unsafe field conditions.

- **Force of Nature and Climate Change**

  The SDG&E service territory features a diverse range of micro-climates and weather conditions. Customers and electric infrastructure are dispersed among sparsely populated lower deserts and mountainous regions, as well as in densely populated load centers along the coastal and inland regions of San Diego and south Orange County. Climate conditions include: sunny skies and mild temperatures, Santa Ana and elevated wind conditions that can exceed 100 miles per hour (MPH) gusts near transmission and distribution infrastructure, heat waves and peak loads in spring, summer and fall months causing unexpected volumes of transformer overloads, heavy rainfall across all regions of the service territory resulting in flash floods, landslides, and the resulting electric infrastructure failures, and ice loading causing pole failures in the inland regions.

  Various combinations of these regional and seasonal conditions call for corresponding operating procedures, several types of advanced protective equipment, and strategic hardening of infrastructure. The intermittency of distributed and bulk renewable generation also introduces added variability in the operating status on any given day.

  Other natural forces that could have an adverse impact on SDG&E's electric infrastructure could include earthquakes and aftershocks, tsunamis causing the destruction of local generation, transmission, and distribution infrastructure, and 100-year floods, and sea level rise. While climatologists have projected sea level rise along SDG&E's coastal region to occur steadily over the course of the next 50-100 years, an unexpected acceleration of this schedule could cause extensive damage to coastal infrastructure, including generation, transmission, and distribution systems. The corrosive nature of the salt contained in sea water could cause extensive underground cable system failures, and the standing water along the base of wooden pole structures could significantly accelerate the deterioration cycle if these types of infrastructure are not fortified or otherwise reconfigured.

Current climate science is indicating that the extreme risk scenarios that SDG&E has been subjected to will continue to change in the years and decades to come. The most recent science and vulnerability assessments completed by SDG&E indicate that the SDG&E electric system more likely will be exposed to the following events:

- Increased number of planned work cancellations due to high fire concerns
    - Includes government-issued restrictions in national forestland
- Acceleration of sea level rise:
    - Low-lying substations and underground facilities susceptible to flooding
    - Potential for prolonged outages due to accessibility issues during flood events
    - Salt water inundation may increase corrosion
- Increase in temperature :
    - Increase in peak electricity demand, despite renewable resources
    - Less efficient power production and reduced substation capacity due to warmer nights
    - Shortened lifespan of transformers due to accelerated break-down of insulation
    - Sagging lines and additional damages due to thermal expansion of electric infrastructure
    - Potential for policy revisions and need to adapt to evolving regulations and standards set by the government and CPUC
        - Planned outage programs to perform needed work and upgrades become susceptible to more frequent cancellations
        - Statewide emissions regulations and restrictions on water use may impact availability of power imports during summer
- Change in rainfall patterns:
    - Reduced efficiency due to less water availability
    - Inundation of, or erosion around, underground electric facilities during flood events
    - Delays in repair/maintenance due to storms

SDG&E will continue to study the effects of climate change on its service territory. See the Climate Change Adaptation risk chapter in this Report for additional details regarding SDG&E's baseline and proposed measures for mitigating this risk.

Table 3 maps the specific drivers of Electric Infrastructure Integrity to SDG&E's risk taxonomy.

Table 3: Operational Risk Drivers

<table>
<tr><th>Driver Category</th><th>Electric Infrastructure Integrity Driver(s)</th></tr>
<tr><td>Asset Failure</td><td>• In-service equipment past its useful life, becomes obsolete (i.e., aging electric infrastructure), or does not operate in accordance with modern safety standards
• In-service equipment overloaded beyond specifications
• In-service equipment failing prematurely
• In-service equipment designed to protect other assets failing to operate as designed (e.g., switch/relay) failing to operate as designed
• In-service equipment failing with lack of or delayed utility awareness
• In-service equipment failing in excessive volumes</td></tr>
<tr><td>Asset-Related Information Technology Failure</td><td>• Failure of Energy Management Systems (EMS), SCADA, or other critical operational systems that could prevent timely control of power flow</td></tr>
<tr><td>Employee Incident</td><td rowspan="2">• In-service equipment not designed for operation in accordance with modern safety standards</td></tr>
<tr><td>Contractor Incident</td></tr>
<tr><td>Public Incident</td><td>Not applicable</td></tr>
<tr><td>Force of Nature</td><td>• In-service equipment failing due to acute climates</td></tr>
</table>

3.3 Potential Consequences

If one or more of the risk drivers listed above were to occur, resulting in an incident, the potential consequences, in a reasonable worst case scenario, could include:

- Major incident resulting in serious injuries;[5]
- Major incident causing significant, short-term environmental impacts;
- Operational impacts, such as prolonged outages;
- Finding(s) of non-compliance;
- Adverse litigation and related financial impacts; and/or
- Erosion of public confidence.

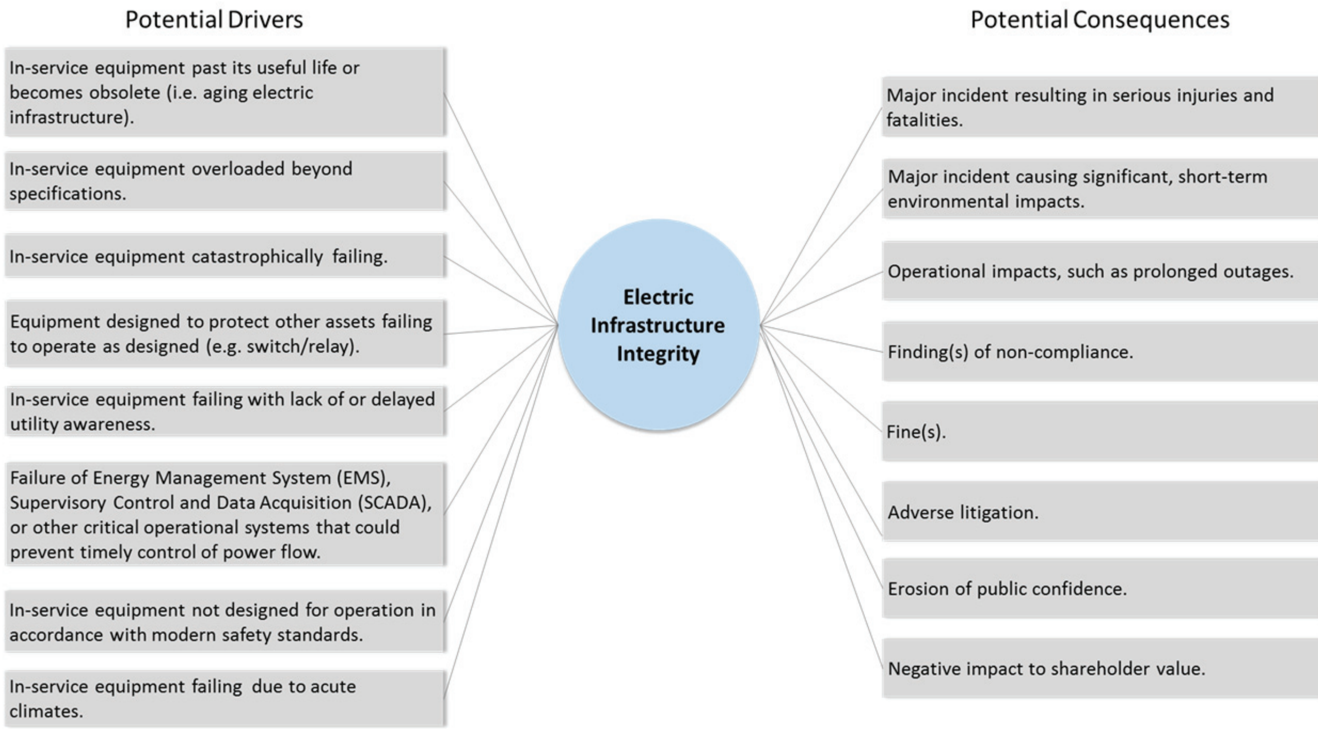
These potential consequences were used in the scoring of Electric Infrastructure Integrity that occurred during the SDG&E's 2015 risk registry process. See Section 4 for more detail.

[5] During the 2015 risk registry process, the consequences associated with this risk were scored to be limited to serious injuries. Following the 2015 risk registry, subject matter experts determined that a consequence could be a fatality.

3.4 Risk Bow Tie

The risk "bow tie," shown in Figure 1, is a commonly-used tool for risk analysis. The left side of the bow tie illustrates potential drivers that lead to a risk event and the right side shows the potential consequences of a risk event. SDG&E applied this framework to identify and summarize the information provided above.

Figure 1: Risk Bow Tie



4 Risk Score

The SDG&E and SoCalGas ERM organization facilitated the 2015 risk registry process, which resulted in the inclusion of Electric Infrastructure Integrity as one of the enterprise risks. During the development of the risk register, subject matter experts assigned a score to this risk, based on empirical data to the extent it is available and/or using their expertise, following the process outlined in this section.

4.1 Risk Scenario – Reasonable Worst Case

There are many possible ways in which an electric infrastructure integrity incident can occur. For purposes of scoring this risk, subject matter experts used a reasonable worst case scenario to assess the impact and frequency. The scenario represented a situation that could happen, within a reasonable timeframe, and lead to a relatively significant adverse outcome. These types of scenarios are sometimes referred to as low frequency, high consequence events. The subject matter experts selected a reasonable worst case scenario to develop a risk score for Electric Infrastructure Integrity:

- An energized wire down event occurs due to overhead electric infrastructure failure. While energized, the downed wire caused arcing, fires, and damage to structures, causing serious injuries to anyone within the ground vicinity. This event also results in claims, litigation and associated financial impacts.

Note that the following narrative and scores are based on this scenario; they do not address all consequences that can happen if the risk occurs.

4.2 2015 Risk Assessment

Using this scenario, subject matter experts then evaluated the frequency of occurrence and potential impact of the risk using SDG&E's 7X7 Risk Evaluation Framework (REF). The framework (also called a matrix) includes criteria to assess levels of impact ranging from Insignificant to Catastrophic and levels of frequency ranging from Remote to Common. The 7X7 framework includes one or more criteria to distinguish one level from another. The Commission adopted the REF as a valid method to assess risks for purposes of this RAMP.[6] Using the levels defined in the REF, the subject matter experts applied empirical data to the extent it is available and/or their expertise to determine a score for each of four residual impact areas and the frequency of occurrence of the risk.

Table 4 provides a summary of the Electric Infrastructure Integrity risk score in 2015. This risk has a score of 4 or above in the Health, Safety, and Environmental impact area and, therefore, was included in the RAMP. These are residual scores because they reflect the risk remaining after existing controls are in place. For additional information regarding the REF, please refer to the RAMP Risk Management Framework chapter within this Report.

Table 4: Risk Score

Residual Impact				Residual Frequency	Residual Risk Score
Health, Safety, Environmental (40%)	Operational & Reliability (20%)	Regulatory, Legal, Compliance (20%)	Financial (20%)		
4	4	5	4	4	5,112

[6] D.16-08-018 Ordering Paragraph 9.

4.3 Explanation of Health, Safety, and Environmental Impact Score

An energized wire down event could lead to a few serious injuries to the public or employees, and/or significant and short-term impacts to the environment. Subject matter experts gave this potential Health, Safety, and Environmental impact a score of 4 (major) in 2015. Following the 2015 scoring, SDG&E realized that a Safety Score to a 6 (extensive) is more representative of the risk scenario due to the fact that a fatality or serious injury also could occur as a result of inadvertent electrical contact involving an energized wire down.

Overhead conductors in SDG&E's service territory are of various vintages and sizes with various corresponding types of connectors. Design and construction considerations include load growth, General Order (GO) 95 and other mandated construction requirements, and other traditional planning guidelines. Other design considerations, such as latest known local weather conditions, civil/structural and environmental conditions, communication infrastructure provider (CIP) attachments, vegetation, and third party incidents (e.g., car-pole contact), are also be considered.

Initial data analysis results suggest wire down events occur more often in smaller, older electric infrastructure, most notably #4 and #6 conductors, in areas with potentially elevated winds. Conductor sizes #4 and #6 make up 22% and 21% of SDG&E's installed overhead circuit miles, respectively; however, together make up over 70% of wire down events in the last five years. Modern system protection devices on the electric transmission and distribution systems often adequately safeguard against these risks as these wire down events occur. Some events, however, are not easily detectable, such as when the load side of a fallen conductor contacts the ground (as opposed to the line side, connected to the energy source). In these types of events, a fallen wire may potentially remain energized until utility personnel arrive on scene. This situation could cause a safety hazard for both the public and utility personnel, due to risk of electrocution.

Notable baseline mitigation activities are in place to address the concerns associated with wire down events, which are reflected in the risk score. These baseline controls are discussed in more detail in Section 5.

4.4 Explanation of Other Impact Scores

Based on the selected reasonable worst case risk scenario, the following scores were assigned to the remaining residual risk categories.

- **Operational and Reliability:** A score of 4 (major) was given to this risk impact area. The occurrence of a local transmission, substation, or distribution outage has the potential to affect more than 10,000 customers (not more than 50,000), impact a critical location, or disrupt electrical service greater than one day. For example, if a single 69/12 kV transformer were to fail during a peak load period, resulting in a 12 kV bus outage, subject matter experts estimated that over 10,000 customers could be affected for several hours while crews work to reroute power from other sources.

- **Regulatory, Legal, and Compliance:** A score of 5 (extensive) was given to this risk impact area. The occurrence of an event resulting in notably adverse impacts to public or employee safety and reliability may result in governmental or regulatory investigations and enforcement actions lasting longer than one year.
- **Financial:** A score of 4 (major) was given to this risk in the Financial impact area because the occurrence of an event may result in potential financial losses between $10 million and $100 million, attributable to litigation (as discussion in the Regulatory, Legal, and Compliance impact area) or other causes.

4.5 Explanation of Frequency Score

Subject matter experts used empirical data to the extent available and/or their expertise to give a score of 4 (occasional) to the likelihood of a downed wire causing arcing, fires, and damage to structures, and causing serious injuries to anyone within the ground vicinity. This is defined in SDG&E's 7X7 risk matrix as having the potential to occur once every 3-10 years in the service territory. This is reasonable, in large part, because of the mitigations and controls that have been implemented to help prevent injuries as a result of asset failures.

5 Baseline Risk Mitigation Plan[7]

As stated above, Electric Infrastructure Integrity risk is the occurrence of a safety, environmental, or reliability incident due to equipment or asset failure caused by a variety of conditions. The 2015 baseline mitigations discussed below include the current evolution of the utilities' risk management of this risk. The baseline mitigations have been developed over many years to address this risk. They include the amount to comply with laws that were in effect at that time.

The risk of Electric Infrastructure Integrity can also be characterized by several possible scenarios, including the wire down event used for risk impact and frequency scoring that involves asset failures. Asset age remains the single most predictable and impactful attribute leading to the natural decline of electric infrastructure integrity. Aged assets not only can demonstrate severe wearing due to weathering and electrical or mechanical use, but also may not reflect the benefit of various improvements made to technology over time with regard to safe design, installation techniques, material quality, and function. Also, it may be more difficult to maintain and operated aged assets due to lack of spare parts and vendors support. Given these conditions, aged infrastructure generally is operated with heightened caution, sometimes using special procedures, for the safety of workers and the public.

SDG&E's baseline mitigation plan consists of four categories of controls: (1) Premature Overhead Failure, (2) Premature Underground Failure, (3) Premature Substation Failure, and (4) System Modernization. Subject matter experts from the Electric Transmission and Distribution Engineering

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[7] As of 2015, which is the base year for purposes of this Report.

Department collaborated to identify and document them. This section provides an overview of the controls and examples of the projects and/or programs included in the mitigation.

These controls focus on safety-related impacts[8] (i.e., Health, Safety, and Environment) per guidance provided by the Commission in D.16-08-018,[9] as well as controls and mitigations that may address reliability.[10] Accordingly, the controls and mitigations described in Sections 4 and 5 address safety-related impacts primarily. Note that the controls and mitigations in the baseline and proposed plans are intended to address various events related to Electric Infrastructure Integrity, not just the scenario used for purposes of risk scoring.

1. Premature Overhead Failure

SDG&E considers the overhead electrical system to be its primary concern, from a risk perspective, because of public safety and its susceptibility to weather. SDG&E is aware, and tracks the age, of its infrastructure; however, it is the premature failure of assets that potentially leads to the most significant issues. SDG&E addressed such concerns with various mitigation projects and programs in 2015.

An example of a control in this category is SDG&E's Corrective Maintenance Program (CMP). In accordance with General Order 165, SDG&E performs routine inspections of overhead electric infrastructure to assess the condition of its equipment and to proactively identify potential safety risks and reliability issues associated with poles, crossarms, conductors, connectors, and other equipment. The program also entails proactive replacement of major assets such as poles, in order to prevent forced interruptions and the resulting public safety hazards. CMP is a reasonable and effective control for electric infrastructure risks because it implements comprehensive, routine inspections of various components of overhead and underground electric infrastructure, supplemented with timely corrective actions to replace assets prone to premature failure.

2. Premature Underground Failure

The underground electrical system poses operational and public safety risks. The underground infrastructure represents the majority of SDG&E's electric distribution infrastructure, is often significantly aged, and is naturally subject to several environmental factors that may accelerate premature failures, such as soil conditions, flooding, and dig-ins by third parties. In 2015, SDG&E continued to implement longstanding programs to remove known vintages of poor performing cable (e.g., unjacketed cables) and utilized predictive analytical methods to identify cables most prone to

[8] The Baseline and Proposed Risk Mitigation Plans may include mandated, compliance-driven mitigations.
[9] D.16-08-018 at p. 146 states "Overall, the utility should show how it will use its expertise and budget to improve its safety record" and the goal is to "make California safer by identifying the mitigations that can optimize safety."
[10] Reliability typically has an impact on safety. Accordingly, it is difficult to separate reliability and safety.

failure. In addition, in contrast to the overhead electric distribution system, underground connections and terminations are significantly larger pieces of equipment and may often pose additional safety risks to the public and workers. Also in 2015, SDG&E continued to implement the routine removal of "live front" terminators and transformers, which are devices not designed in accordance with modern safety protocols. These devices were generally replaced with "dead front" devices, which enable workers to operate the devices in a safer manner that limits the exposure to energized equipment. These mitigation actions are reasonable and effective because they systematically reduce or eliminate underground electric risks known to be among the greatest historical concerns to electric workers and/or contractors who build and maintain these assets.

3. Premature Substation Failure

There are unique complexities associated with substation infrastructure, including heavy reliance on protective relaying devices, and antiquated assets as old as 70-80 years with limited operational flexibility. Electric substation infrastructure is generally isolated from public view or contact. Electric workers, however, may be subject to electric safety hazards such as arcing, high voltage induction stray voltages, and mechanical safety hazards associated with working with heavy equipment (e.g. cables) and in confined spaces, such as in metalclad switchgear.

In 2015, SDG&E continued to expand the deployment of the Condition Based Maintenance (CBM) program, which installed monitoring devices that help to provide foresight on substation asset health such as transformers. This information is key to appropriately planning and implementing maintenance schedules that help to prevent prolonged, forced interruptions due to equipment failures, and the safety concerns associated with working around these risk-prone assets. This mitigation directly addresses the premature nature of substation asset failures in a manner that is prudent: it avoids and reduces safety risk, optimizes capital investment while reducing maintenance costs, and empowers the organization with data to help experts understand the long-term causes of substation asset failure.

4. System Modernization

Modern electric infrastructure uses technology that leverages recent engineering techniques that conform to the latest environmental and physical standards, and advanced monitoring and telecommunications to increase situational awareness. SDG&E works continuously to modernize its electric infrastructure to mitigate and control risks of antiquated equipment. It uses advanced technologies to detect and respond timely to risks as well as to maintain situational awareness of electric infrastructure at all times, especially when there is potential for accidental public or worker contact with energized equipment. Proactively deployed technologies aid in SDG&E's 24-hour monitoring; however, failures or limitations of the systems may inhibit the safe isolation or restoration of inevitable asset failures. Protective systems (e.g., switches with protective relays) help to address this as they are designed to quickly isolate and de-energize damaged equipment, minimizing customer outage and other risk exposure. These protection systems are tailored to specific scenarios and also may fail to operate (mechanical or communication failure), mis-operate (e.g., under or over-sensitivities), or not operate effectively due to an unforeseen circumstance that exceeded design criteria.

In 2015, SDG&E continued to expand the deployment of advanced SCADA systems, featuring switching and communication infrastructure with phasor measurement units (PMU). These PMUs sample and measure data with exceptional granularity, capturing 30 samples of voltage and other data per second, and transmitting the data back to a central logic and control unit at the substation. This enhances situational awareness and enables real-time analysis of potentially energized wire down events. These capabilities provide SDG&E with an intelligent, wire down risk mitigation option to compare with more conventional methods of undergrounding, upgrading conductors, or redesigning an overhead circuit's configuration. SDG&E believes Advanced SCADA systems can play an increasingly important role in ensuring the availability of expedient, effective, and cost-conscious solutions wire down risk mitigation.

6 Proposed Risk Mitigation Plan

The 2015 baseline mitigations outlined in Section 5 will continue to be performed in the proposed plan, in most cases, to maintain the current residual risk level, along with the incremental (expanded and new) mitigations being proposed in the years 2017, 2018 and 2019. These are described below.

1. <u>Premature Overhead Failure</u>

One of the primary concerns of SDG&E with respect to its overhead equipment is when a piece of overhead equipment (e.g., wires) that falls to the ground remains energized, also referred to as a wire down event. If an employee, contractor or the public comes into contact with an energized wire, the results can be fatal. Accordingly, SDG&E is continuing to take proactive measures to determine the cause of such events.

Data analysis suggests there are various drivers of wire down events, such as third-party contact, acute weather causing vegetation and foreign object contact, aged infrastructure, and degradation of connectors. The most notable and consistently contributing driver of wire down events is the failure of small wire on three phase systems. In evaluating the overall safety risk of these wire down events, it was determined that the highest safety risks exist where one wire and one span from the load side on a three phase system falls and makes contact with the ground. In this situation, the conductor can remain energized even though upstream protection devices, such as single phase fuses, have operated as designed. After the wire makes contact with the ground, although the circuit is considered "open" from the source side, backfeed from adjacent phases connected to downstream transformers, as well as customer generation sources, that remain online, may cause the downed wire to remain or become energized. If a customer or worker were to come in contact with this downed wire prior to the creation of further isolation points (such as opening a 3-phase switch upstream) serious injury or death may occur due to electrical contact.

SDG&E is proposing a Wire Correction Program, which will effectively replace or protect the assets most prone to failure. The Wire Correction Program uses historical data collected from actual wire down events to estimate failure rates of overhead infrastructure as they may relate to causing wire down events. Applying these failure rates to all non-FTZ circuits provides SDG&E subject matter experts with an estimate of an individual circuit's expected likelihood of a wire down event over a given period.

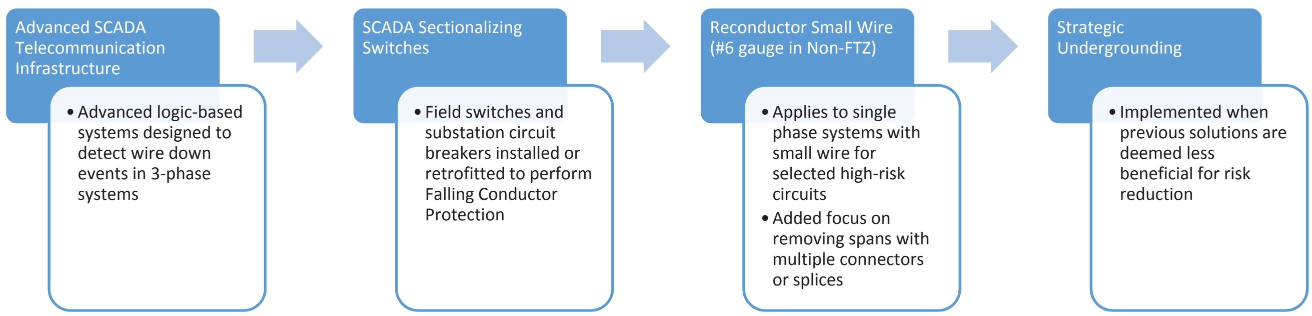
SDG&E ranks these individual circuits by the total expected number of wire down events to identify the top quartile where risk reductions may be concentrated. This top quartile of potential wire down events encompasses the circuits with the most exposure of high-risk assets, primarily #6 gauge small wire, and most notably to address spans greater than 500 feet in length. Also, other environmental factors including high winds, accelerated corrosion in coastal areas, likelihood of public contact, and areas where wire down events have occurred more than usual, are considered when estimating failure rates.

The proposed strategy to mitigate the risk of energized wire down events caused by overhead infrastructure failures involves deploying Falling Conductor Protection (FCP) in non-FTZ areas where several contiguous spans of three-phase #6 small wire exist. FCP, an SDG&E developed technology, enables the fastest-known detection and isolation (switching) available. By sensing the wire down event and de-energizing the wire while the conductor is falling to the ground, this technology is expected to significantly reduce the risk of energized conductor making contact with the ground. Several additions or upgrades to the infrastructure are needed to support FCP:

- Addition of line monitoring infrastructure in strategic areas where communication is available or otherwise can be made available.
- Addition or upgrade of existing sectionalizing switches equipped with Phasor Measurement Unit (PMU) technology. Due to the nature of the design, FCP may operate successfully to reduce the risk of energized down wires; however, with some potential reduction in local electric reliability. As designed, when a falling conductor is detected by the FCP system, the nearest upstream FCP-enabled switch will trip open to isolate the damage. The switch may or may not be the nearest isolating device, such as a fuse, which would limit the outage exposure to fewer customers. The PMU technology would help limit potential degradation in reliability.
- Control and communication upgrades consisting of a Phasor Data Concentrator (PDC), RTAC, GPS, advanced relays, and other related components. The substation needs to have these upgrades to control the complexed series of added protection systems, which will operate in parallel to other existing protection systems.

Where FCP cannot be deployed to protect at-risk small wire, the alternative is to replace remaining small wire with larger conductor that is known to be statistically less prone to failure, such as #2 5/2 AWAC conductor. In other areas, where small wire may not feasibly be replaced, at-risk connectors, sleeves, and single phase spans of small wire (commonly known failure points) will be replaced as needed. Where appropriate, at-risk overhead facilities also may be undergrounded. Figure 2 depicts the proposed Wire Correction Program:

Figure 2: Summary of Proposed Wire Correction Program



The proposed Wire Correction Program aims to address the top 25% of projected wire down risks over a 10-year period.

Additionally, SDG&E is proposing a program that focuses on pole loading. With nearly 240,000 distribution poles, it is imperative that SDG&E maintains accurate data pertaining to the structural integrity and safety of each structure. Current, detailed, and accurate pole loading calculations and as-built documentation identifying the condition of poles are important for SDG&E to be able to assess the safety of assets. Major pole-related events, including fire ignition, causing injury or death to public and/or Company personnel, and damage to infrastructure or homes, may be driven by severe weather conditions or other third-party events. It is important to note that while SDG&E strives to maintain up-to-date information for pole integrity, a large share of SDG&E's distribution poles also have attachments owned and maintained by other utilities, such as communication infrastructure providers (CIP). Major failures of this third-party infrastructure, could cause substantial adverse safety, environmental, operational, reliability, regulatory, and financial implications to the Company as experienced by other similar utilities.

The proposed Post-Construction True-Up Quality Assurance and Quality Control (QA/QC) program provides dedicated personnel, activities, and tools to proactively identify and correct pole loading issues through activities including data analytics, engineering, training, and validation or improvement of construction standards and work methods. The proposed program would supplement the existing Corrective Maintenance Program (CMP) by steadily improving construction quality, as well as placing greater emphasis (identification and timeliness of mitigation) on field follow-up for poles with high risk of failure. The program would implement routine inspections to capture data to further evaluate if poles meet safety standards. Upon the discovery of potentially unsafe conditions, timely reinforcements or replacements would be implemented to achieve risk reduction and improve safety.

Another area of concern is the 4 kV distribution system as a whole. This is because an aged system requires significant efforts to upgrade to a 12 kV voltage level. While the 4 kV system collectively serves approximately 5% of SDG&E's customer load, this system represents a much more significant share, 22%, of the number of distribution circuits. These 4 kV circuits are operated with older system protection and control technologies, making them far more susceptible to certain reliability issues for longer periods of time. Additionally, wire down occurrences, as a proportion of the amount of infrastructure currently installed (downed spans per 100 miles conductor), are up to twice as frequent on the 4 kV system when compared to 12 kV over the last five years.

Over the last several years, SDG&E has worked to modernize the 4 kV distribution system by converting or rebuilding the infrastructure to 12 kV, which provides additional technological flexibility such as advanced system protection, stronger conductors and hardware, and structural improvements due to new pole sets or undergrounding. SDG&E routinely upgrades 4 kV distribution to 12 kV through various planning channels, such as through undergrounding programs coordinated with local cities, and capacity-based upgrades and rearrangements.

4 kV generally serves fewer customers when compared to 12 kV due to natural capacity limitations. Because 4 kV operates at a higher current than 12 kV by an approximate factor of three, fewer customers can be served by the same volume of infrastructure on 4 kV compared to 12 kV. For example, a 12 kV distribution circuit typically provides up to 600 amps of load, which can equate to over 2,000 homes. A 4 kV distribution circuit typically provides up to 200 amps of load, which can equate to approximately 200-300 homes. For comparison, a total of three 4 kV circuits would be required to operate at the same 600-amp conductor rating, which would equate to these three 4 kV circuits serving approximately 600-900 homes for the same current rating as 12 kV, which can serve over three times more customers. Due to the age of 4 kV infrastructure, SDG&E must perform the inspection and maintenance procedures more closely, and with more caution. An upgrade to 12 kV would reduce the effort and time to perform this work.

SDG&E is proposing a 4 kV Modernization program, which aims to continue traditional conversions of the 4 kV systems, including substations and both underground and overhead, to 12 kV standards. These upgrades would enable better protection against risks such as wire down events. Replacement of these 4 kV facilities also inherently adds resilience to the distribution infrastructure as the majority of these assets are severely aged and naturally prone to failure and the consequential forced outages.

2. Premature Underground Failure

Aged and/or corroded overhead and underground (padmount or subsurface) distribution switches have a higher propensity for failure and/or inoperability during an outage (or for extending the impact of an outage to the next upstream protection device), causing a prolonged forced outage as crews are required to install additional jumpers or other workarounds. Switches that are constantly ("normally") closed or constantly opened (e.g., tie switches) are at increased risk of being inoperable when needed. The inoperable state of the switch poses safety risks to field operating personnel due to potential flash or overexertion by the employee.

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SDG&E is proposing a Switch Maintenance Program for both underground and overhead switches. This program aims to systematically and thoroughly inspect all distribution switches. These inspections are expected to include visual inspections, infrared (IR) inspection to detect points of potential overheating, switch lubrication, and physical exercising. Upon inspection, if a switch is found to not be safe for continued operation, field experts will make the determination to replace the switch with an appropriately superior or equivalent asset, depending on field conditions. This program supplements existing programs to replace SF6 and DOE switches, which were previously identified to be at-risk due to their environmental and potential arcing hazards, respectively. This program is expected to significantly improve worker safety while operating these switches, and prevent premature failures of these assets, avoiding potential for injuries and damages to adjacent facilities.

Also, SDG&E is also proposing to continue and expand its Proactive Cable Replacement program. This program aims to identify underground cables that are aged or otherwise prone to failure according to data trends. Along with these cable replacements, other related assets, such as 600-amp tee connectors, will be replaced.

To supplement the Wire Correction Program addressing Premature Overhead Failures, strategic overhead-to-underground conversions also are proposed as a mitigation program in areas where Falling Conductor Protection and replacement of small conductor are not sufficient to mitigate wire down risks.

3. Premature Substation Failure

The adverse impact of aging electric infrastructure is illustrated by a failure (internal fault) of a 4 kV package substation. These aged units feature an integrated 12/4 kV transformer, circuit breaker, and associated electromechanical controls and relaying. As compared to current distribution substation operations, where such assets are physically separated and operated/maintained independently, these package substations operate and fail as a unit. These package substations are no longer an SDG&E standard due to their limited flexibility and potential safety concerns.

The customers these substations support, may be susceptible to a multi-day outage, should an emergency occur, as few flexible tie switches to adjacent circuits are available, and SDG&E works to build customized, temporary primary feeds for the area. SDG&E would be faced with constructing facilities in a relatively small workspace, as the existing package substation currently is constructed per older design standards.

SDG&E's Substation Equipment Assessment (SEA) team routinely reviews all major substation assets, including the units described above, and works to remove and/or upgrade substation infrastructure. While SDG&E has removed a substantial share of 4 kV substations to date, 4 kV substation assets often were replaced with 12/4 kV step-down transformers as semi-permanent solutions. These step-down units do not provide electric isolation points for as safe and reliable an operation as the modern 12 kV system.

The proposed 4 kV Modernization program aims to remove these aged substation assets. Load served by the connected 4 kV distribution circuits would be cutover to 12 kV circuits as part of the 4 kV distribution risk mitigation efforts previously described. Removal of the substation assets alleviates operational and safety risks by no longer requiring electric workers to work with equipment not designed to SDG&E's current safety requirements. Where replacement substation assets are required to serve the load cutover from 4 kV to 12 KV, such as circuit breakers and relays, this upgrade program will provide the opportunity to modernize the equipment to perform added functions that support safe and risk-mitigating operations such as the detection and prevention of energized wire down events.

Also, SDG&E is proposing to expand Condition Based Maintenance (CBM) infrastructure to include Transmission and Substation Battery assets. These programs will enable data gathering to better predict future failures and understand how to develop and maintain best safety practices when operating these devices. These systems also enable timely maintenance practices to better assess asset health.

4. System Modernization

SDG&E's service territory features electric infrastructure of various vintages, some dating back to the 1920s. Associated with older infrastructure are classic techniques for managing the assets categorized by common failure modes and generally known life expectancies for the general population. In contrast, associated with infrastructure constructed in recent decades are techniques, equipment, and tools to operate infrastructure more safely and effectively. The proposed System Modernization mitigations aim to address the replacement or improvement of infrastructure that, to SDG&E's knowledge, are expected to fail or otherwise cause potential safety risks in the near to medium term; within 1-10 years. Infrastructure expected to fail in a shorter timeframe are replaced or otherwise isolated for safety as soon as practical.

Modern infrastructure is expected to operate under much different conditions than older infrastructure. The conventional "centralized station" uni-directional power delivery model is now commonly transformed to the distributed generation model to accommodate reverse power flow caused, for example, by rooftop solar systems. As these are intermittent generation systems, the Company is now faced with challenges associated with load and generation resource forecasting at the community, circuit, substation, and transmission levels. Until the systems are modernized, SDG&E's data analytics capability is limited. As an abundance of modern operational (e.g., SCADA, Synchrophasors, Advanced Meter Infrastructure [AMI]) and customer (e.g., AMI) data becomes available, the Company could potentially safeguard against future widespread asset failures by identifying trends years before the expected date of failure. It is important for engineers and operators to identify common causes for failures that may not be inherently obvious due to the shift from the conventional power delivery system to the distributed generation system, to properly invest in and plan for deployment of future technologies. Failure to adapt to new data analytics methods may result in SDG&E's inability to diagnose failures, develop and implement permanent solutions, and lead to unnecessary capital and operational expenses associated with temporary solutions.

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SDG&E is proposing to expand and accelerate the implementation of its Advanced SCADA Program across all electric distribution systems. The Advanced SCADA systems will improve safety and reliability by increasing situational awareness through the use of highly granular, real-time monitoring, enabling advanced, logic-based automation and control, and further enabling long-term data gathering for advanced analytics and predictive asset failure modeling. This program also provides a platform for SDG&E to continue its work in developing new risk identification and mitigation techniques, similar to Falling Conductor Protection.

7 Summary of Mitigations

Table 5 summarizes the 2015 baseline risk mitigation plan, the risk driver(s) a control addresses, and the 2015 baseline costs for Electric Infrastructure Integrity. While control or mitigation activities may address both risk drivers and consequences, risk drivers link directly to the likelihood that a risk event will occur. Thus, risk drivers are specifically highlighted in the summary tables.

SDG&E does not account for and track costs by activity, but rather, by cost center and capital budget code. So, the costs shown in Table 5 were estimated using assumptions provided by SMEs and available accounting data.

Table 5: Baseline Risk Mitigation Plan[11]
(Direct 2015 $000) [12]

ID	Control	Risk Drivers Addressed	Capital[13]	O&M	Control Total[14]	GRC Total[15]
1	Premature Overhead Failure*	• Asset Failure	$16,040	$1,180	$17,220	$16,460
2	Premature Underground Failure*	• Asset Failure	33,110	n/a	33,110	33,110

[11] Recorded costs were rounded to the nearest $10,000.
[12] The figures provided in Tables 5 and 6 are direct charges and do not include Company overhead loaders, with the exception of vacation and sick. The costs are also in 2015 dollars and have not been escalated to 2016 amounts.
[13] Pursuant to D.14-12-025 and D.16-08-018, the Company is providing the "baseline" costs associated with the current controls, which include the 2015 capital amounts. The 2015 mitigation capital amounts are for illustrative purposes only. Because projects generally span several years, considering only one year of capital may not represent the entire mitigation.
[14] The Control Total column includes GRC items as well as any applicable non-GRC jurisdictional items. Non-GRC items may include those addressed in separate regulatory filings or under the jurisdiction of the Federal Energy Regulatory Commission (FERC).
[15] The GRC Total column shows costs typically presented in a GRC.

ID	Control	Risk Drivers Addressed	Capital[13]	O&M	Control Total[14]	GRC Total[15]
3	Premature Substation Failure	• Asset Failure	4,190	n/a	4,190	1,450
4	System Modernization	• Asset Failure	570	50	620	620
	TOTAL COST		$53,910	$1,230	$55,140	$51,640

* Includes one or more mandated activities

While all the controls and baseline costs presented in Table 5 contribute to mitigating this risk, some of the controls also may contribute to mitigating other risks presented in this RAMP Report. The potential drivers for this risk are similar to those described in other risk chapters: Employee, Contractor, and Public Safety, Climate Change Adaptation, Wildfire Caused by SDG&E Equipment, and Public Safety Event – Electric. The respective risk chapters aim to address distinctions among these risks' consequences and resulting mitigation plans. For example, the Wildfire chapter focuses on risk mitigations addressing *fire risks* caused by electric infrastructure, but not necessarily injuries caused by failed electric infrastructure. Similarly, the Employee, Contractor, and Public Safety risk chapter focuses on training and public awareness campaigns to prevent avoidable electric safety incidents. Nonetheless, because the mitigation activities mitigate multiple risks in this Report, SDG&E is presenting both the costs and risk reduction benefits in this chapter as well as the aforementioned risks.

Table 6 summarizes SDG&E's proposed mitigation plan, associated projected ranges of estimated O&M expenses for 2019, and projected ranges of estimated capital costs for the years 2017-2019. It is important to note that SDG&E is identifying potential ranges of costs in this plan, and is not requesting funding approval. SDG&E will request approval of funding, in its next GRC. There are non-CPUC jurisdictional mitigation activities addressed in RAMP; the costs associated with these will not be carried over to the GRC. As set forth in Table 6, the utilities are using a 2019 forecast provided in ranges based on 2015 dollars.

Table 6: Proposed Risk Mitigation Plan[16]
(Direct 2015 $000)

ID	Mitigation	Risk Drivers Addressed	2017-2019 Capital[17]	2019 O&M	Mitigation Total[18]	GRC Total[19]
1	Premature Overhead Failure*	• Asset Failure	$177,340 - 230,540	$8,320 - 10,810	$185,660 - 241,350	$183,820 - 238,970
2	Premature Underground Failure*	• Asset Failure	215,140 - 279,680	1,280 - 1,660	216,420 - 281,340	216,420 - 281,350
3	Premature Substation Failure	• Asset Failure	37,550 - 48,810	260 – 340	37,810 - 49,150	28,820 - 37,470
4	System Modernization	• Asset Failure	26,170 - 34,020	680 - 890	26,850 - 34,910	26,850 - 34,910
	TOTAL COST		$456,200 - 593,050	$10,540 - 13,700	466,740 - 606,750	$455,910 - 592,680

☐	Status quo is maintained
☐	Expanded or new activity
*	Includes one or more mandated activities

1. .Premature Overhead Failure

The costs associated with the incremental activities were developed based on historical data of similar programs as well as SME judgement. SDG&E also used high level assumptions regarding the work to be completed as part of these programs. For example, to develop the forecasted costs for the Wire Correction Program, SDG&E assumed that a percentage of the scope would be the implementation of FCP technology, while another percentage would be the undergrounding activities. A range of costs is provided to accommodate the refinement of scope and work plans for each wire, circuit, pole, etc., that will occur according to the findings of the inspection process.

2. Premature Underground Failure

The costs associated with the incremental activities were developed based on historical data of similar programs, as well as SME judgment. SDG&E also used high level assumptions regarding the work to be

[16] Ranges of costs were rounded to the neared $10,000.
[17] The capital presented is the sum of the years 2017, 2018, and 2019 or a three-year total. Years 2017, 2018 and 2019 are the forecast years for SDG&E's Test Year 2019 GRC Application.
[18] The Mitigation Total column includes GRC items as well as any applicable non-GRC items.
[19] The GRC Total column shows costs typically represented in a GRC.

completed as part of these programs. For example, to develop the forecasted costs for the Switch Maintenance Program, SDG&E assumed that a percentage of the maintenance inspections would result in recommended capital replacements; the actual number of replacements will only be known after a thorough inspection is completed as part of the program. A range of costs is provided to accommodate the refinement of scope and plan for each switch that will occur during the inspection process.

3. Premature Substation Failure

The costs associated with the incremental activities were developed based on historical data of similar programs as well as SME judgment. SDG&E also used high level assumptions regarding the work to be completed as part of these programs. For example, SDG&E assumed two 4 kV substation removals/conversions will be designed, engineered, and [de]constructed per year utilizing existing resources, taking into account similar resource limitations for converting the distribution assets to 12 kV. A range of costs is provided to accommodate the refinement of scope and plan for each substation that will occur during the design process.

4. System Modernization

The costs associated with the incremental activities were developed based on historical data of similar programs as well as SME judgment. SDG&E also used high level assumptions regarding the work to be completed as part of these programs. For example, to develop the forecasted costs for the Advanced SCADA Program, SDG&E projected costs using a 4-year average for similar programs. As SDG&E's design of these systems employs various technologies suited for diverse field conditions, the actual required equipment is not yet identified, and will be determined upon field surveying and project development.

For each of the mitigations, SDG&E is proposing to continue its baseline work and forecasted such costs using mostly five-year averages, which is most representative because the amount and complexity of work can vary on an annual basis. The future scope of work is largely consistent with the baseline. In some cases, where the future scope of baseline work is proposed to expand or accelerate, zero-based forecasts were used to estimate costs.

8 Risk Spend Efficiency

Pursuant to D.16-08-018, the utilities are required in this Report to "explicitly include a calculation of risk reduction and a ranking of mitigations based on risk reduction per dollar spent."[20] For the purposes of this Section, Risk Spend Efficiency (RSE) is a ratio developed to quantify and compare the

[20] D.16-08-018 Ordering Paragraph 8.

effectiveness of a mitigation at reducing risk to other mitigations for the same risk. It is synonymous with "risk reduction per dollar spent" required in D.16-08-018.[21]

As discussed in greater detail in the RAMP Approach chapter within this Report, to calculate the RSE the Company first quantified the amount of Risk Reduction attributable to a mitigation, then applied the Risk Reduction to the Mitigation Costs (discussed in Section 7). The Company applied this calculation to each of the mitigations or mitigation groupings, then ranked the proposed mitigations in accordance with the RSE result.

8.1 General Overview of Risk Spend Efficiency Methodology

This subsection describes, in general terms, the methods used to quantify the *Risk Reduction*. The quantification process was intended to accommodate the variety of mitigations and accessibility to applicable data pertinent to calculating risk reductions. Importantly, it should be noted that the analysis described in this chapter uses ranges of estimates of costs, risk scores and RSE. Given the newness of RAMP and its associated requirements, the level of precision in the numbers and figures cannot and should not be assumed.

8.1.1 Calculating Risk Reduction

The Company's SMEs followed these steps to calculate the Risk Reduction for each mitigation:

1. **Group mitigations for analysis:** The Company "grouped" the proposed mitigations in one of three ways in order to determine the risk reduction: (1) Use the same groupings as shown in the Proposed Risk Mitigation Plan; (2) Group the mitigations by current controls or future mitigations, and similarities in potential drivers, potential consequences, assets, or dependencies (e.g., purchase of software and training on the software); or (3) Analyze the proposed mitigations as one group (i.e., to cover a range of activities associated with the risk).
2. **Identify mitigation groupings as either current controls or incremental mitigations:** The Company identified the groupings by either current controls, which refer to controls that are already in place, or incremental mitigations, which refer to significantly new or expanded mitigations.
3. **Identify a methodology to quantify the impact of each mitigation grouping:** The Company identified the most pertinent methodology to quantify the potential risk reduction resulting from a mitigation grouping's impact by considering a spectrum of data, including empirical data to the extent available, supplemented with the knowledge and experience of subject matter experts. Sources of data included existing Company data and studies, outputs from data modeling, industry studies, and other third-party data and research.
4. **Calculate the risk reduction (change in the risk score).** Using the methodology in Step 3, the Company determined the change in the risk score by using one of the following two approaches to calculate a Potential Risk Score: (1) for current controls, a Potential Risk Score was calculated that represents the increased risk score if the current control was not in place; (2) for incremental mitigations, a Potential Risk Score was calculated that represents the new risk score if the

[21] D.14-12-025 also refers to this as "estimated mitigation costs in relation to risk mitigation benefits."

incremental mitigation is put into place. Next, the Company calculated the risk reduction by taking the residual risk score (See Table 4 in this chapter.) and subtracting the Potential Risk Score. For current controls, the analysis assesses how much the risk might increase (i.e., what the potential risk score would be) if that control was removed.[22] For incremental mitigations, the analysis assesses the anticipated reduction of the risk if the new mitigations are implemented. The change in risk score is the risk reduction attributable to each mitigation.

8.1.2 Calculating Risk Spend Efficiency

The Company SMEs then incorporated the mitigation costs from Section 7. They multiplied the risk reduction developed in subsection 8.1.1 by the number of years of risk reduction expected to be realized by the expenditure, and divided it by the total expenditure on the mitigation (capital and O&M). The result is a ratio of risk reduction per dollar, or RSE. This number can be used to measure the relative efficiency of each mitigation to another.

Figure 3 shows the RSE calculation.

Figure 3: Formula for Calculating RSE

$$Risk\ Spend\ Efficiency = \frac{Risk\ Reduction * Number\ of\ Years\ of\ Expected\ Risk\ Reduction}{Total\ Mitigation\ Cost\ (in\ thousands)}$$

The RSE is presented in this Report as a range, bounded by the low and high cost estimates shown in Table 6 of this chapter. The resulting RSE scores, in units of risk reduction per dollar, can be used to compare mitigations within a risk, as is shown for each risk in this Report.

8.2 Risk Spend Efficiency Applied to This Risk

SDG&E analysts used the general approach discussed in Section 8.1, above, in order to assess the RSE for the EII risk. The RAMP Approach chapter in this Report, provides a more detailed example of the calculation used by the Company.

SDG&E used the following approach to assess the RSE of the mitigations:

(1) Current and Incremental activities were grouped according to asset type, resulting in four asset classes: OH, UG, Subs, and Systems. A single representative asset type was then used to evaluate each of the bundled proposals. Consequently, four current controls and four incremental mitigations were analyzed.
(2) Weights were applied to each of the asset classes according to potential safety impact to account for their contributions to the risk:

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[22] For purposes of this analysis, the risk event used is the reasonable worst case scenario, described in the Risk Information section of this chapter.

a. OH is assigned the highest weight (greater than 50%) as it is considered a larger contributor to this risk due to the public accessibility of this asset class.
b. Underground assets were assigned the next highest weight (between 25 and 50%) as they are not as easily accessible by the public.
c. Substation and Systems were assigned a low weight (less than 5%) since these assets are fenced in and/or have not been a significant cause of safety incidents in the industry.

(3) The risk reduction of each mitigation was calculated and the current and incremental programs were unbundled, with slightly more benefit allocated to the baseline programs as they are ongoing and therefore generally address higher priority risks.

The resulting risk to the system should all the mitigations NOT be funded was estimated to occur Regularly (Frequency at level 5 to 6), potentially causing serious injuries or even fatalities (safety impact at level 6). The corresponding risk score could then potentially reach approximatively 800,000 in the long term. This is based on SME projected degradation and system aging. Lack of aggressive maintenance procedures would cause the electric system to become more susceptible to failures and it is important to note the fact that some similar risk events have caused fatalities within the industry. While eliminating all risk is not achievable, the Company is proposing to continue, expand, accelerate, and implement new mitigations to keep the risk level from increasing. While data models for some electric assets are mature, the company recognizes that it does not have an analytical basis for the resulting risk of all electric assets and will be pursuing an analytical approach and models to better quantify the risk of Electric Infrastructure Integrity.

- **Overhead assets**

Circuits prone to wire down events were used as a proxy for the OH asset class. OH is assigned the highest weight (greater than 50%) as it is considered a larger contributor to this risk due to the public accessibility of this asset class. Since not all targeted circuits prone to wire down events are being addressed by this mitigation over the time period of interest (2017-2019), it was necessary to pro-rate in the risk reduction the amount of the percentage being addressed or approximately 10%. There is also an adjustment for the relative effectiveness of these wire down remedial actions that is applied in the risk reduction calculation. The number used is two times the average, meaning that the assets targeted by the program have been shown to contribute two times as much per unit to this risk than the average asset.

- **Underground equipment**

For this asset class, underground cable information was used as a proxy due to the availability of data for this asset, even though most of the safety risk is caused by the associated equipment. This risk represents an estimate of potential electrical contact incidents from working with live front transformers, "do not operate energized" (DOE) switches, in confined spaces, and other underground electric assets. Underground assets were assigned the next highest weight (between 25% and 50%) as they are not as easily accessible by the public; however, they make up the majority (greater than 60%) of SDG&E's electric facilities.

The percentage of poor performing assets slated to be replaced in the UG group is very small, less than 0.5%, and this percentage is used to prorate the program's benefits. From all Company underground assets, almost 25% were deemed poor performing, and this percentage is used as an additional factor to prorate the benefit of the program. Even though the percent slated for replacement is very small, the effectiveness of these reconstruction measures is estimated to be much larger than represented by the average condition; the effectiveness factor was estimated at 10 times the average.

- **Substation assets**

For this grouping, 4 kV substation data was used as a proxy. Note that because of access restrictions in substations, it is much less likely that inadvertent electrical contact can occur and therefore a small weight (less than 5%) was assigned to this asset class.

Substations with 4 kV voltage on the low side were used as the proxy for the asset class percentage being remediated. The number proposed is 6 out of 29 substations slated for remediation activities, and this ratio is used as a benefit deflator. However, it should be noted that there are over 150 step-down transformers that are in the 4 kV transformer fleet and that are not located in a traditional enclosed substation facility.

Severely aged substation infrastructure across all voltage levels are replaced based on operational significance and SDG&E reliability standards. Targeted programs also include obsolete equipment and relay replacements. Approximately 10-20 substations are targeted each year for this type of work.

- **System Modernization**

For this grouping, a percentage of switches targeted for remediation was used as a proxy. The assigned weight of this asset class is very small (less than 5%).

The proposed number of switches targeted for inspection and remediation and used as the proxy for the percentage of poor performing assets being remediated is more than half of the targeted population. This percentage is used as a risk deflator.

The risk mitigation strategy for System Modernization includes expanding and maintaining distribution Advanced SCADA infrastructure. This project deploys switches and other devices equipped with Advanced SCADA capabilities; using high speed broadband radios and logic-based controls to reduce safety risks by quickly and more accurately identifying infrastructure failures. The devices feature advanced high impedance fault detection and falling conductor detection in addition to traditional protection such as overcurrent protection. In lieu of these systems, electric infrastructure failures and their associated outages and safety risks could remain undetected or unconfirmed for extended periods of time while first responders are en route. Approximately twenty-five circuits per year are targeted for Advanced SCADA expansion.

<u>**Qualitative Ranking of Mitigation Groupings**</u>

Table 7 below shows the ranking of mitigation classes based on safety impacts:

Table 7: Qualitative Risk Ranking

Class	**Assets**	**SME Rank**
Current OH	Conductors/Connectors (impacting wire down), pole loading	**1**
Incremental OH	True up QA/QC, 4kV modernization, distribution rebuild, long spans, small wire and connectors, coastal infrastructure, anchor rods, UAV switches	**2**
Current Systems	Advanced SCADA	**3**
Current UG	Cable, live front transformers, DOE switches, services, CMP switches and manholes	**4**
Incremental Systems	SCADA RTUs, bridged cutout switches	**5**
Current Subs	Aged infrastructure, CBM	**6**
Incremental Subs	CBM expansion, 4kV modernization	**7**
Incremental UG	Undergrounding, tee connectors	**8**

The above rankings are believed to be reasonable because they aim to address risks in order of highest safety risk to the public, contractors, or employees. Current OH mitigations implement critical routine maintenance and inspections of overhead infrastructure, which are most prone to safety incidents due to their physical exposure to outside forces (e.g. wind, storms) and collocation with the public. The Incremental OH mitigations aim to expand and accelerate these practices, however systematically address mostly medium-to long-term risks as projected by data models based on known failure rates. Technological advancements and modernization efforts such as Advanced SCADA are valuable because they support fast, real-time operations for other risk-mitigating activities across all asset classes. The Current Systems mitigations address highest risk areas whereas the Incremental Systems mitigations address areas of growing concern.

Subs and UG mitigations are ranked lower due to the assets' limited physical exposure to the public. Substations are typically located in areas not generally traversed by the public and are also enclosed by a secured wall or fence. For utility workers in substations, various safety protocols are strictly enforced to help ensure safety, such as the utilization of visual disconnect switches and gauges to identify open or de-energized circuits. Underground facilities, which include subsurface (e.g., vault, manhole, conduit) structures and above-ground pad-mounted structures, are relatively less susceptible to public or worker safety due to the modern design of these systems. In the event of a cable fault or public contact of a pad-mounted transformer station, damaged assets are often effectively automatically isolated from inadvertent electrical contact or are otherwise away from public contact. Current UG and Subs activities are ranked higher than Incremental UG and Subs because the existing programs aim to address infrastructure with the highest rate of failure primarily due to age. The Incremental UG and Subs mitigations aim to expand and accelerate these efforts to ensure safety is steadily maintained in proportion to the rate of failure.

Quantitative Ranking of Mitigation Groupings

With the unbundling of the risk reduction benefits into proposed and baseline portions, the various programs can be re-ranked. The Quantitative Rank column in Table 8 shows the re-ranked sequence based on the quantitative analyses that were performed.

Table 8: Quantitative Risk Ranking

Class	Assets	SME Rank	Quantitative Rank
Current OH	Conductors/Connectors (impacting wire down), pole loading	**1**	**1**
Incremental OH	True up QA/QC, 4kV modernization, distribution rebuild, long spans, small wire and connectors, coastal infrastructure, anchor rods, UAV switches	**2**	**2**
Current Systems	Advanced SCADA	**3**	**3**
Current UG	Cable, live front transformers, DOE switches, services, CMP switches and manholes	**4**	**7**[23]
Incremental Systems	SCADA RTUs, bridged cutout switches	**5**	**4**

[23] The difference in ranking is due to the use of underground cable data as a proxy which may under represent the UG class safety risk.

Current Subs	Aged infrastructure, CBM	**6**	**5**
Incremental Subs	CBM expansion, 4kV modernization	**7**	**6**
Incremental UG	Undergrounding, tee connectors	**8**	**8**

It is important to note that the electric infrastructure programs are intended to maintain current performance and to address potential adverse impacts from system aging and degradation.

8.3 Risk Spend Efficiency Results

Based on the foregoing analysis, SDG&E calculated the RSE ratio for each of the proposed mitigation groupings. Following is the ranking of the mitigation groupings from the highest to the lowest efficiency, as indicated by the RSE number:

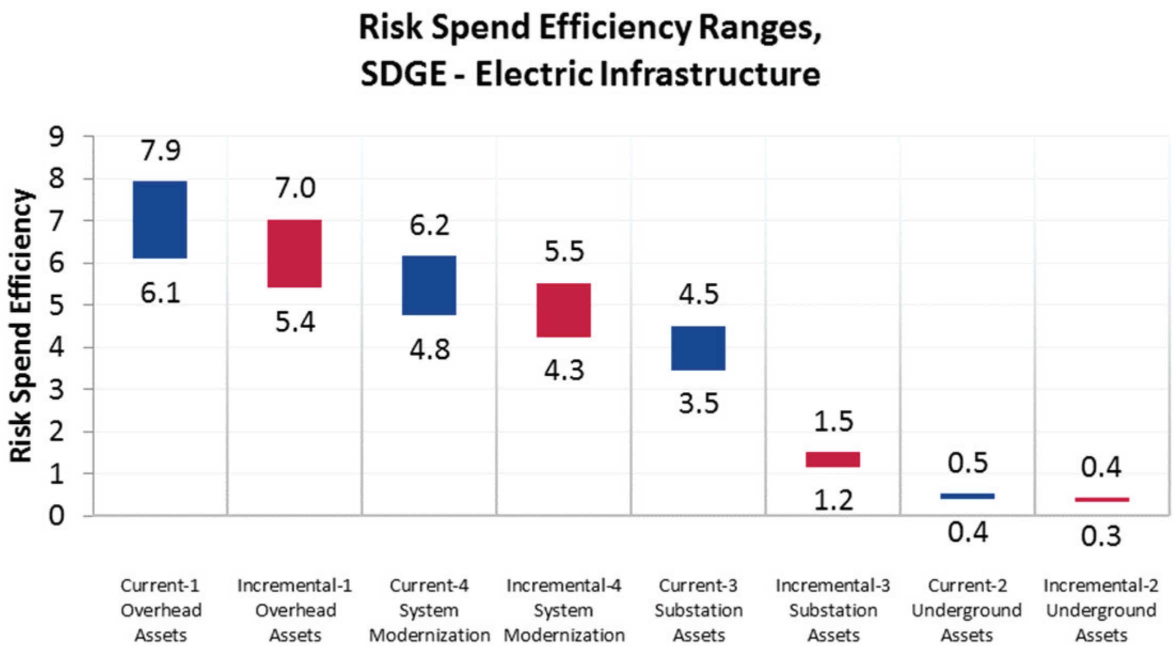
1. Overhead Assets (current controls)
2. Overhead Assets (incremental mitigations)
3. System Modernization (current controls)
4. System Modernization (incremental mitigations)
5. Substation Assets (current controls)
6. Substation Assets (incremental mitigations)
7. Underground Assets (current controls)
8. Underground Assets (incremental mitigations)

Figure 4 displays the range[24] of RSEs for each of the SDG&E EII risk mitigation groupings, arrayed in descending order.[25] That is, the more efficient mitigations, in terms of risk reduction per spend, are on the left side of the chart.

[24] Based on the low and high cost ranges provided in Table 6 of this chapter.

[25] It is important to note that the risk mitigation prioritization shown in this Report, is not comparable across other risks in this Report.

Figure 4: Risk Spend Efficiency



9 Alternatives Analysis

SDG&E considered alternatives to the proposed mitigations as it developed the proposed mitigation plan for the Electric Infrastructure Integrity risk. Typically, alternatives analysis occurs when implementing activities, and with vendor selection in particular, to obtain the best result or product for the cost. The alternatives analysis for this risk plan also took into account modifications to the proposed plan and constraints, such as budget and resources.

9.1 Alternative 1 – Comprehensive Replacements

SDG&E considered comprehensive replacements as an alternative to the proposed plan. This would include replacing entire classifications of risk-prone assets with assets less impacted by the same risk drivers. For example, a comprehensive replacement of all #6 conductor in the SDG&E service territory with #2 conductor could be very costly, while not eliminating an incremental amount of risk that is proportional to those costs when compared to the proposed mitigation strategy, which incorporates a hybrid solution involving Advanced SCADA. While there are benefits to this alternative, such as a greater amount of enterprise risk reduction, they do not seem to justify the anticipated high cost of implementing comprehensive replacements. Therefore, this alternative was dismissed in favor of SDG&E's proposed plan, due to the affordability and feasibility constraints.

9.2 Alternative 2 – Extended Period of Replacements

Another alternative considered was to extend the period by which SDG&E replaces aging infrastructure. This would reduce the cost in the short term due to less work being completed in a given year, but it also would increase the risk exposure for an extended period of time. SDG&E does not believe this is a feasible alternative as these aging assets already have been deemed as needing to be replaced. If adopted, this alternative could potentially cause SDG&E to reduce system reliability, as these aging assets begin to fail in larger volumes than currently experienced; disproportionate to workforce and logistical capacity. Accordingly, this alternative was rejected. SDG&E's proposed plan is preferred as it better balances affordability, timeliness, and the resulting risk reduction.

9.3 Alternative 3 – Expedited Undergrounding and Reconductoring

This alternative involves expediting undergrounding and reconductoring plans to reduce the amount of overhead wire exposure. This acceleration could provide more immediate safety and reliability benefits as it would replace equipment that is more prone to failure; but would do so at a high cost (based on historical costs to underground distribution lines). Regarding the reconductoring approach, risks may not be fully mitigated, as the overhead infrastructure still would be susceptible to energized wire down events due to foreign object contact (e.g., car-pole contact). SDG&E's proposed plan is preferred as it is less costly and directly addresses the safety risk associated with wire down events.

9.4 Alternative 4 – Work-Around Switching Procedures and Status Quo

This alternative maintains the status quo, which comprises work-around switching procedures, enabling electric workers to avoid directly operating equipment that is suspected to be unsafe, at the cost of prolonged outages. While the projects and programs currently administered allow SDG&E to provide safe and reliable service today, every day SDG&E's assets are getting older, which again is a potential leading indicator of the likelihood of failure. This alternative is more cost -effective than SDG&E's proposed plan. However, deferring asset replacements increases the risk exposure. SDG&E's proposed plan is preferred as it is expected to reduce risk.