Power Delivery Master Plan

Prepared by Pasadena Water and Power

Power Delivery Master Plan (PDMP)

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1. EXECUTIVE SUMMARY

The Power Delivery Master Plan ("PDMP") provides a high-level guide for planning, operating, and maintaining the electric distribution system for the City of Pasadena Water and Power Department ("PWP") over the next 20 years (Fiscal Years 2023-2042). The plan also identifies the long-term outlook of the electric utility, assesses its current conditions, and provides an ambitious capital improvement plan to address current and future challenges all designed to increase reliability, safety, and improve cost effectiveness.

The PDMP incorporates PWP's mission and vision in development of realistic goals to provide safe and reliable electric services and modernize the electric distribution system to ensure its cost effectiveness to its customers.

Mission Statement: PWP is committed to providing safe and reliable water and power with superior customer service at reasonable rates.

Vision Statement: PWP will be a valued community asset, an exceptional employer, a partner in Pasadena's prosperous future, and contribute to the quality of life in Pasadena.

Over a two-year period, key stakeholders who represented the diversity of the City provided expectations and insight to PWP, which was used to develop the goals and establish the foundation for the PDMP. Five primary goals provide the basis for all recommended actions and capital improvement programs. The goals are as follows:

- Reliability and Safety
- Resiliency
- Power Quality
- Grid Modernization
- Grid Edge (Technology that is customer facing, installed at the "edge" of the grid)

PWP is committed to providing safe and reliable electric service that residents and businesses of Pasadena have been accustomed to receiving for more than a century. The PDMP outlines the plan to execute on this commitment, and optimizes capital expenditures to leverage new technologies and select projects that accomplish multiple goals at once.

The Plan identifies the optimum asset maintenance, inspection, and replacement cycles. It also provides a Capital Improvement Plan ("CIP") framework for the next two decades and a detailed 5-year plan that outlines resource requirements needed to achieve the PDMP goals.

PWP's electric distribution system is reliable, but has an aging infrastructure, and has a few crucial areas that need to be addressed systematically. There are over one hundred projects outlined in this plan to achieve PWP's goals. The following section summarizes the major efforts of the PDMP and the challenges for each, along with a high-level schedule:

Aging Infrastructure

- The metering assets will be replaced with Advanced Metering Infrastructure ("AMI") within 4 years.
- Electric distribution assets will continuously be replaced after conducting dynamic risk analyses.
- Sub-transmission cable upgrades and voltage conversions (4kV to 17kV) are prioritized to improve reliability and capacity.

Grid Edge

- The replacement of meters with an AMI system will provide customers new rate options, online portal to view interval usage, as well as provide PWP improvements to power system efficiency and outage restoration capabilities.
- Trends in adoption of electric vehicles ("EV"), solar, and energy storage systems are considered.

Power Import Limitation

- The installation of a phase shifting transformer installed at the interconnection point with the Los Angeles Department of Water and Power ("LADWP") within seven years is being evaluated. This installation would increase the amount of load PWP can serve and increase the redundancy of the City's power sources, and provide a second usable external utility connection to the Pasadena power system.
- The 220kV transformers at the interconnection with Southern California Edison ("SCE") will be upgraded within 10 years to increase the power import capacity to from 280MW to PWP's contracted 336 megawatt ("MW") import limit.

Power Flow Constraints

- The capacity and protection of the 35kV "mini cross-town" sub-transmission lines that connect to the Receiving Stations through the Substations will be upgraded within five years to increase the overall system power flow capability. Once upgraded, these lines can be configured to provide a second "cross-town" connection for redundancy and improved capacity. This upgrade is necessary before PWP can upgrade the existing 35kV "cross-town" sub-transmission lines between Glenarm and Santa Anita Receiving Stations.
- The aging 35kV "cross-town" sub-transmission lines between Glenarm and Santa Anita Receiving Stations will be replaced within 10 years.

High Short Circuit Duty (~40kA)

The short circuit duty in the 35kV sub-transmission system will be reduced to 25KA within 10 years. To accomplish this, PWP plans to upgrade the existing T.M. Goodrich Receiving Station ("TMG") transformers, and may electrically split the 35kV sub-transmission system. This will help to significantly reduce potential damage to the distribution assets should faults (short circuits) occur.

Program Costs and Updates

The total capital cost of this plan will be approximately $250.5 million over the next five years. PWP will incorporate the annual projected capital expenses into PWP's annual budget and the rolling five-year financial plan to develop appropriate funding strategies to provide balanced budgets for both capital and operating needs.

PWP will review this plan annually and may make minor adjustments in line with the primary goals. A comprehensive review will be conducted in five years to address major changes such as revision of primary goals, technology advancements, and change in forecasted demand.

1.1. Primary Goals

1. Reliability and Safety:
    - Maintain and reduce outage frequency and duration
    - Maintain and/or replace equipment proactively
    - Reduce electric system risks caused by natural disasters, such as wildfires, windstorms, and heatwaves

2. Resiliency:
    - Improve power flow and increase system import capability and capacity
    - Establish a second interconnection to import power to the City from external sources
    - Reduce the system fault current duty

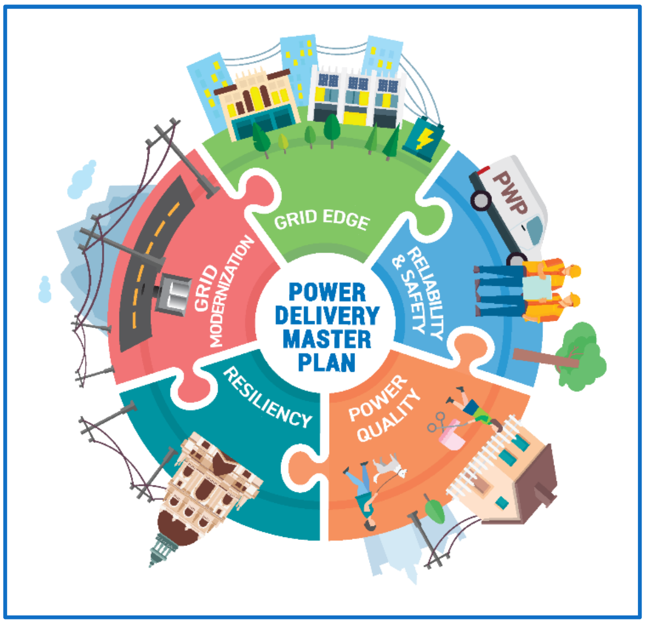


Figure 1: Master Plan Goals

3. Power Quality:
    - Provide a clean and stable voltage to customer meters between 114 and 126 Volts
    - Complete targeted 4 kV to 17 kV voltage conversion projects

4. Grid Modernization:
    - Improve real-time monitoring, control, analysis, and reporting of the electric system (Automation)
    - Implement advanced technologies to allow remote outage detection and restoration capabilities
    - Upgrade protection, monitoring, and control systems and equipment (relays, communications, and operational software)

5. Grid Edge:
    - Implement AMI
    - Expand PWP's Electric Vehicle charging infrastructure to meet growing demand

1.2. <u>System Limitations</u>

The following are a list of the high-level system limitations which drive the majority of the CIPs:

1.2.1. Import limitations at T.M. Goodrich Receiving Station

The sub-transmission system delivers power from both the Glenarm Power Plant and the California Independent System Operator ("CAISO") grid at the TMG to the distributing substations. Presently, TMG serves as the City's main source of power, with its physical import capacity limited to 280 MW to account for Western Electricity Coordinating Council ("WECC") single outage contingencies ("N-1"). PWP's contracted limit to import power is 336 MW. After studying several alternatives, the preliminary recommended solution to increase the import capacity to support PWP's forecasted peak loads is to replace the three existing aged receiving station transformers with larger transformers and upgrade the 220 kV system's protection schemes. The proposed solution will allow PWP to operate at the forecasted peak load without requiring the use of local generation.

1.2.2. Short Circuit Duty Limitations on 35 kV System

Figure 2: Glenarm Receiving Station Circuit Breakers

PWP faces an issue with the maximum available short circuit duty ("SCD") on the 35 kV system, which may exceed the interrupting ratings of the 35 kV circuit breakers (40kA). This limits PWP's ability to dispatch all of its five generators while the three receiving station transformers are in service at TMG. In this instance, PWP must continuously switch its receiving station transformers at TMG when four or five PWP generators are dispatched.

This is both resource intensive and adds unnecessary stress on the equipment. PWP is currently studying the feasibility to install current limiting reactors on the 35 kV system to reduce the available SCD, allowing PWP to operate its 35 kV system under any scenario.

1.2.3. Power Flow Limitations on 35 kV System

PWP evaluated the 35kV sub-transmission lines and determined that most of the sub-transmission conductors between the receiving stations need to be upgraded in the next 20 years to support the transfer of power across the City during peak demand. The proposed replacement and upgrade projects consists primarily of cable replacements, which are crucial to keeping PWP's reliability under any N-1 contingency.

1.2.3.1. Aging Substation Units

The 4 kV substation units (each unit includes two substation transformers and their related switchgear) have reached or exceeded the recommended life expectancy. PWP plans to systematically replace each substation unit based on a dynamic criticality, health, and risk analysis. Efforts to convert 4 kV circuits to operate at 17 kV will continue in coordination with substation unit replacements.

Figure 3: Typical 4kV Substation Unit

PWP will also replace all aging electromechanical relays in the distribution substations and receiving stations with new microprocessor-based relays. The new relays will allow PWP to accurately record fault events, remotely control assets, and improve flexibility on protective coordination schemes.

1.3. Guiding Principles of the PDMP

The PDMP exists to support the utility's long-term goals to ensure that the system is safe, reliable, resilient, and efficiently operated. It provides strategic guidance for major capital investment decisions to gradually replace and upgrade PWP's system assets as needed, in an effort to minimize the financial burden to its customers. The plan will also focus on modernizing the electric system through the deployment of smart grid technologies to support system automation, Distributed Energy Resources ("DER"), Battery Energy Storage Systems ("BESS"), AMI, a Distribution Management System ("DMS"), Electric Vehicle charging infrastructure, and building electrification.

The following are the guiding principles of the PDMP, which were considered before each project's scope was determined:

1. All CIPs shall improve at least one of the PDMP primary goals: the electric system's safety, reliability, resiliency, power quality, and the implementation of grid edge technologies and grid modernization.

2. Annual budgets shall be balanced and efficient, aimed at providing the most optimal cost solution to ensure system integrity without overburdening PWP's customers.

3. All new communication devices, programs, and equipment shall comply with PWP's cybersecurity policy. Cybersecurity assessment needs shall be completed before commissioning any new system to the PWP electric system.

4. All CIPs shall ensure the compliance of PWP with all local, state, and federal regulations and standards regarding the grid operation and safety of the public and staff. Special attention will be paid to environmental requirements and regulations regarding insulating mediums for equipment, and oil spill prevention.

1.4. Capital Expenditure and Staff Resource Needs

The PDMP consists of numerous essential capital improvement projects and programs recommended to maintain a safe and reliable system operation. Table 1 summarizes the five-year capital expenditure by each primary goal:

Table 1: Recommended Power Delivery Capital Improvement Budget (in Millions of USD)

Primary Goal	5-Year Total	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027
Reliability and Safety	$102.8	$12.9	$21.9	$22.5	$20.7	$24.8
Resiliency	$32.5	$3.4	$10.2	$6.4	$2.9	$9.5
Grid Edge	$50.6	$2.3	$4.1	$18.3	$24.0	$2.0
Grid Modernization	$20.1	$5.2	$4.8	$5.5	$2.7	$1.9
Power Quality	$17.8	$3.6	$3.6	$3.6	$3.6	$3.6
PDMP Subtotal	**$223.8**	**$27.4**	**$44.6**	**$56.3**	**$53.8**	**$41.7**
Customer Projects	$26.8	$5.2	$5.3	$5.4	$5.5	$5.6
Grand Total	**$250.5**	**$32.5**	**$49.8**	**$61.6**	**$59.2**	**$47.3**

PWP has determined that existing internal staffing levels, supplemented with outside resources, are adequate to execute the capital projects outlined in the PDMP and properly maintain and operate the system. However, a potential risk is high vacancy rate. PWP needs to keep the vacancy rate as low as possible.

Furthermore, as new technologies and automation are added to the electric system, special skillsets are needed to properly maintain the automated systems. PWP currently is developing these skillsets, however additional resources may be needed as automation continues to grow. PWP will closely monitor and analyze this requirement and determine if additional internal resources are needed to address this concern. Any additional resource requirements will be presented to the City Council in the future as part of the City's annual budgeting process.

1.5. PDMP Chapter Summary

This section summarizes the PDMP discussions and proposals, which are elaborated in more detail within Chapters 3 through 12 of this report.

Chapter 3: Electric System History and Background

This chapter outlines PWP's history as a utility and provides a general background on the scope and high-level design of the City's electric system. PWP utilizes a combination of locally owned gas fired generators and outside resources from long term power supply contracts. The generated and purchased power is transferred across the city through the 35 kV underground sub-transmission system, and then delivered to customers at lower voltages using the distribution system, which is made up of both underground and overhead systems.

Chapter 4: Electricity Demand and Load Projections

PWP follows an electric load forecasting technique to predict the annual power/energy needed to meet the demand within its system. Accuracy with forecasting is critical for the operations of the utility. In the past, electric load had grown at predictable and steady rates based on new customer interconnections to the city's electric grid. Currently, factors such as gas-to-electric conversions of buildings and appliances, energy efficiency programs, and the proliferation of Distributed Energy Resources ("DER") and EVs have drastically changed the trend, making load growth projections more difficult to predict. Nevertheless, PWP considered the aforementioned factors as well as planned customer load additions or upgrades to forecast its future annual peak load and energy requirements for the next 20 years. The results of this forecast will be used for distribution and sub-transmission planning, serving as the basis for which the electric system needs to be able to operate at reliably and safely.

Chapter 5: Power System Planning and Reliability Criteria

The purpose of power distribution system planning is to periodically identify internal and external factors that may influence system performance and evaluate the impacts of these factors on system reliability and power quality. This process is guided by priorities of maintaining safety for the public and City employees, ensuring system reliability, and providing services at reasonable rates. This chapter outlines the general process and criteria which PWP uses to evaluate its electric system at the forecasted peak demand. PWP has standardized many of its planning and reliability criteria based on Institute of Electrical and Electronics Engineers ("IEEE") and American National Standards Institute ("ANSI") standards. Furthermore, the annual review of the distribution and sub-transmission systems provides PWP a great deal of foresight to any potential issues in the system, allowing PWP to proactively target potential problem areas to improve electric service reliability and quality.

Chapter 6: Evaluation of Electric System Reliability

A major concern regarding PWP's system is that it contains a large number of aging assets that may pose reliability risks in the future. In reference to Planning and Reliability Criteria discussed in Chapter 5, this chapter gives a brief overview of the indices used to quantify utilities' reliability, and then summarizes PWP's reliability performance for the past five years. It further delves into the common causes of unplanned outages at PWP and details PWP's plan to address the root cause of these outages.

Chapter 7: Evaluation of the Electric System

This chapter provides a detailed analysis of PWP's infrastructure, summarizes the major equipment categories in terms of their potential risk to system reliability, and recommends a replacement timeline to mitigate these risks. Along with routine replacement of distribution assets, PWP will focus more on replacing the 4kV substation units. Table 2 highlights the recommended annual replacement rate for each of PWP subject assets:

Table 2: Proposed Annual Replacement Rates for PWP Assets

Electric System Asset	Target Asset Replacement Rate per Year
Substation Unit*	1 every 3 Years
Substation Switches	4
Underground Distribution Switches	17
Distribution Transformers	50
Power Poles	120
Electric Vaults (Repair or Replace)	50
Overhead Line (Miles)	4
Underground Line (Miles)	8

*The Substation Unit consists of two transformers, five circuit breakers, and related switchgear.

Chapter 8: Evaluation of Operational Tools and Maintenance Practices

A variety of software tools are used in the planning, operation, and maintenance of the electric system. Key software that will be upgraded as a part of the PDMP may include the Supervisory Control and Data Acquisition (“SCADA”) system, Outage Management System (“OMS”), Asset Management System (“AMS”), and Engineering Analysis (“EA”) tools. PWP will integrate as many software as possible to reduce redundancy and increase the overall effectiveness of each solution. PWP also anticipates the need for a Distribution Management System (“DMS”) to complement the OMS and SCADA systems, and to accommodate the increasing number of distribution automation equipment expected to be added to the system in the coming years.

PWP has rigorous inspection, testing, and maintenance programs to keep the equipment in the system healthy and operational. PWP has done a great job throughout the years in maintaining the electric system assets, which is evident by its excellent system reliability record. PWP currently has an AMS software (Cascade), to manage and track its distribution assets, which is in need of a major upgrade or replacement. The PDMP outlines a plan to replace this system, allowing the utility to digitize its inspection, maintenance, and testing records, and provide mobile inspection solutions. The new system will incorporate a Work Order Management System (“WOMS”) to manage routine work orders generated by inspection activities and capital project.

Chapter 9: Evaluation of Electric Grid Technology

The modernization of utility infrastructure includes the upgrading of systems such as metering, protection and control, and communication. Upgrading to modern devices and systems will offer automation capabilities across the distribution and sub-transmission systems. The major initiatives include upgrading the metering system to an AMI system, upgrading the existing SCADA system to accommodate distribution and substation automation. System automation will improve PWP’ ability to better monitor and control the entire system, improve system reliability and safety, and increase workforce efficiency.

Chapter 10: Future System Upgrades

This chapter summarizes the recommended capital improvement projects and their estimated expenditure amounts for the first five years of the PDMP. It also lists each individual proposed CIP as a part of the PDMP for the following 20 years to help achieve the goals defined in the PDMP. The projects were carefully scheduled to maximize the benefits and life of the system, to minimize the cost to PWP and its customers.

Chapter 11: Staffing and Resource Needs

This chapter summarizes the minimum required staffing and resources needed to complete the projects listed within the PDMP. It’s necessary to utilize a combination of internal employees and outside contracted labor to efficiently meet the labor requirements needed to maintain the system and complete the capital projects outlined in the PDMP. PWP has city and utility driven moratoriums on certain construction projects because of high electric load conditions in the summer and the Rose Parade in the winter. To address these moratoriums, PWP coordinates the timing of the projects and the needed resources to accomplish the work in the opportunity windows available.

PWP analyzed the current staffing level and determined that existing internal employee count supplemented with outside resources (as needed), will be adequate to execute the capital projects outlined in the PDMP and properly operate and maintain the electric system. PWP identified that a high vacancy rate poses a potential risk that may greatly impact the completion of the projects within their budget and schedule. It is essential that PWP maintain a vacancy rate as low as possible.

Chapter 12: Policies, Programs, and Rates

This section summarizes the different policies and programs that PWP may seek to implement in support of the capital projects in the PDMP. The recommended policy changes aim at improving service reliability to customers over the timespan of the PDMP. It also includes a brief discussion on the implications for future policy regarding customer owned DER, and the potential mitigating strategies that PWP may implement to avoid power quality issues being introduced onto the system. Finally, this chapter discusses how PWP may modify the rate structure after the implementation of AMI to support a more equitable cost structure for both the utility and its customers.

2. IMPLEMENTATION PLAN

The PDMP identifies a wide range of capital improvement projects and programs needed for the management, operation, construction and maintenance of Pasadena's electric system. These projects will allow PWP to continue to provide reliable and cost-effective electric service over the next 20 years. This implementation plan is in chronological order, and specifies the activities that PWP should carry out to achieve the goals set-forth in the PDMP and assesses the cost and staffing requirements of such activities. The plan proposes a capital improvement budget averaging about $50 million per year through 2027.

To implement the identified recommendations, PWP will follow a strategy consisting of the following elements:

1. Implement a Project and Work Management System to improve the efficiency and effectiveness of current work management methods.
2. Implement an Asset Management System to improve the effectiveness of asset maintenance and replacement planning.
3. Upgrade the subtransmission facilities at TMG to maximize the import capacity of current interconnection with California Independent System Operators' ("CAISO") grid.
4. Upgrade the existing interconnection with the City of Los Angeles to be usable as a dis-patchable power source.
5. Upgrade the subtransmission lines to significantly reduce power flow limitation on the 35 kV subtransmission system.
6. Conduct feasibility studies and implement practical projects that reduce and/or control the flow of permissible fault current levels within the 35kV subtransmission system.
7. Implement an AMI solution and the related communication network(s) required to achieve substantial grid impacts and benefits for customers and utilities.
8. Install EV charging stations to fulfill PWP's commitment to California's Clean Air Act and to provide a lower cost of transportation for the community.
9. Deploy flexible, customized energy storage solutions to provide an alternative access to PWP reliable sources that will help deferring major distribution system investments.
10. Periodically review and update the existing real-time SCADA solution contracts, equipment, and software specifications.
11. Employ distribution system automation to increase the overall system reliability, reduce outage durations and scope, and increase operational flexibility.
12. Review and update construction contracts, equipment, material specifications, and overhead and underground distribution standards in preparation for a significant increase in infrastructure replacement projects.

13. Continue upgrading aging infrastructure including circuit breakers, oil-filled switches, underground and overhead conductors, underground vaults, wooden power poles, and overhead and underground transformers consistent with their respective useful life.
14. Convert the 4kV distribution system to operate at 17kV in order to increase the distribution system power quality, efficiency, reduce operating costs, and increase distribution system capacity, starting with areas where power quality, aging infrastructure, and equipment loading issues all coincide.
15. Maintain a talented and dedicated work force of internal and external resources that possess skill sets consistent with the work needed at the time.

2.1. First Five-Year Summary of Capital Improvement Projects

Another purpose of this Implementation Plan is to provide an input to the PWP budget planning cycle for the FY 2023-2027 capital budget. The FY 2023 thru FY2027 budget reflects the strategy that emphasizes the implementation of the AMI solution while ramping-up the vital improvements of other major projects. Figure 4 provides the recommended spending levels for the proposed CIP projects for each of the fiscal year starting FY2023 thru FY 2027.

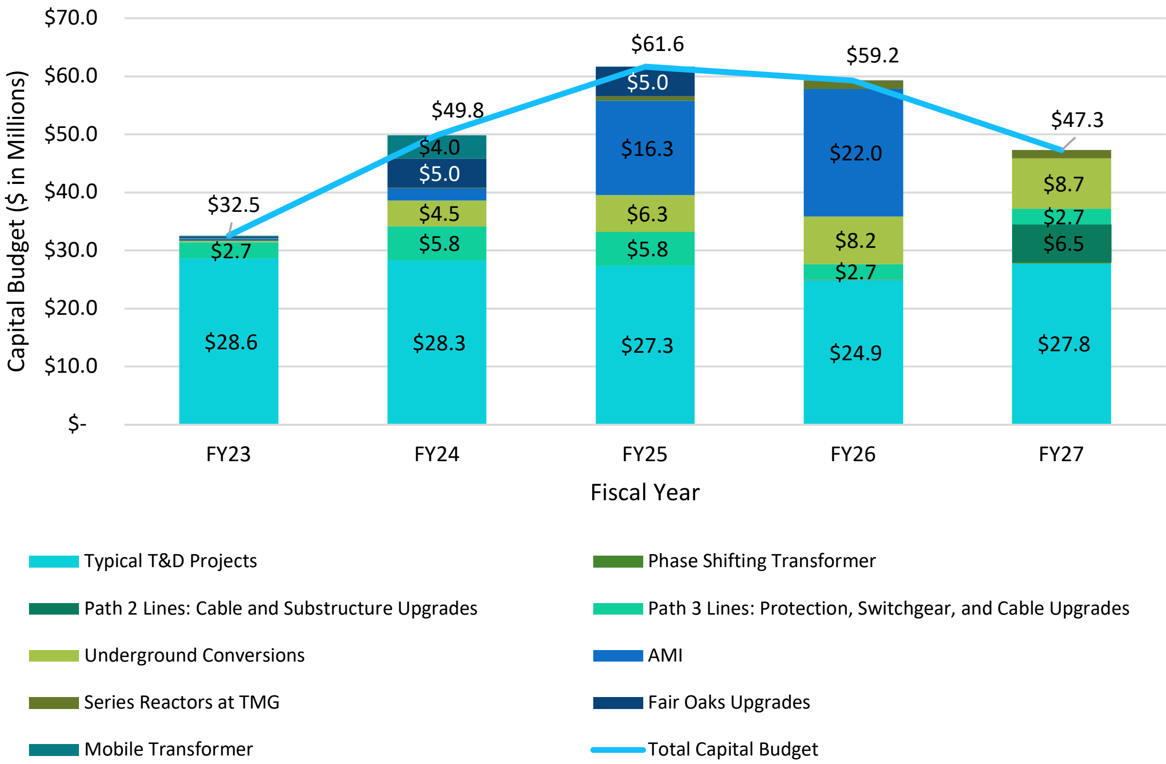


Figure 4: Breakdown of Master Plan Capital Budget for FY23-FY27 ($ in Millions)

The following is a discussion on the implementation of the major projects listed in Table 3 for the first five years of the PDMP:

- **AMI Solution:** PWP is targeting first four years of PDMP (FY2023-2026) to implement this solution and is planning to spend $41 million on this project. The AMI rollout includes the installation of the required communication network upgrades, integration with the new billing system, as well as any required testing.

- **Subtransmission Line Upgrades:** This project to upgrade the cables of the major subtransmission lines (Path 2 lines) and the infrastructure starting in FY2027 is highly dependent on upgrading the cables, protection and switchgear of other subtransmission lines (Path 3 lines). Figure 5 shows a diagram for Path 1, 2, and 3, indicating the proposed projects per fiscal year from FY2023 thru 2027. This project depends on weather conditions between January and June of each year. PWP will execute the following projects in order:
  - Path 3 subtransmission lines upgrade to ensure resiliency:
    - Upgrade Cables for lines 34-4 in FY2023, 34-20 in FY2024, and 34-30 in FY2025 to support the path 3 lines total capacity.
    - Install/upgrade select 35kV switches, switchgear and protection systems at the Oak Knoll, Villa, and Chester for path 3 lines. Complete the upgrades by FY2027 to ensure upgrades are in place before starting the path 2 lines upgrades.
  - Path 2 subtransmission lines upgrade: Start the planning and procurement process in FY2027 to upgrade path 2 subtransmission lines.

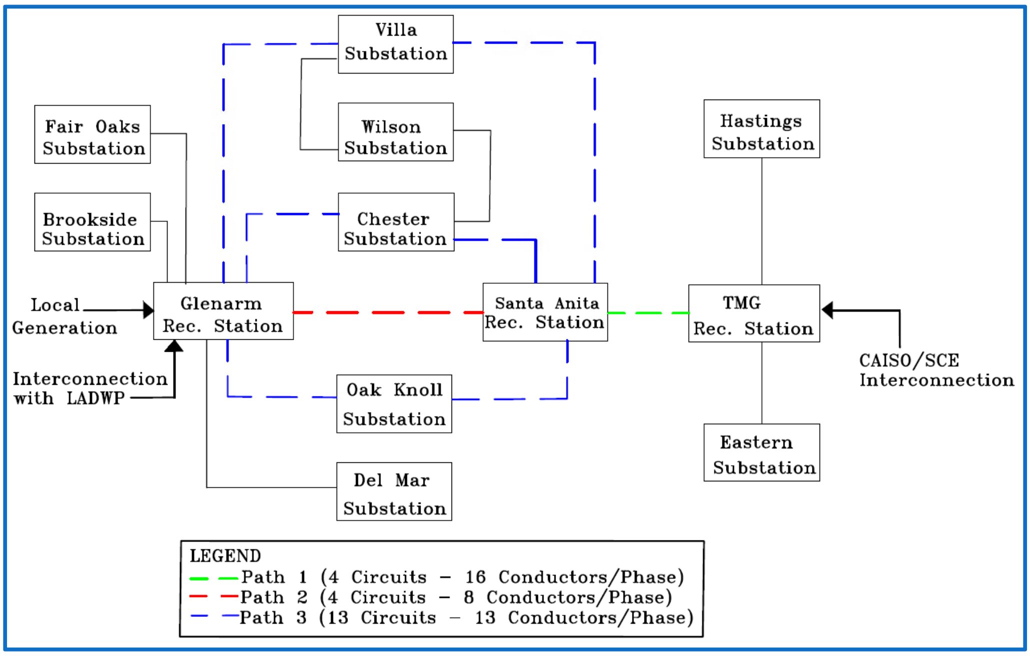


Figure 5: Proposed (per Fiscal Year) Projects to Upgrade Path 1, 2 and 3 Subtransmission Lines

- **Fair Oaks Service Area Upgrades:**
  - PWP is targeting to convert the operating voltage from 4kV to 17kV for select circuits in the Fair Oaks service area in the first five years of the PDMP at a rate of about 0.74 circuit miles per year.

- At the Fair Oaks substation, PWP is planning to upgrade the existing substation unit 3 with a new unit, featuring two larger size transformers with a new 25kV switchgear and circuit breakers by FY2025.
- At the Fair Oaks substation, PWP will also be upgrading the 35kV protection and switches in FY2024-2025 to provide further improvement to the overall reliability and resiliency of the substation.

- **Mobile Transformer:**
  PWP will procure a mobile transformer in FY2024 to serve as a backup option to power substation units in the case of a transformer failure or support other substation replacement projects.

- **Short Circuit Duty Limitation:**
  Starting in FY2023, PWP will start a 5-year project to install series reactors or fault current limiting equipment on the 35 kV network to lower the available fault current on the system. By FY2027, PWP should have the maximum available short circuit duty on the 35 kV network lower than 36,000 Amps, or 90% of the circuit breaker ratings.

- **Import Capacity Upgrades:**
  For system import capacity constraints, PWP will begin its phase shifting transformer project in FY2025 and expect to finish in the FY2028 timeframe. At that time, PWP expects to increase its import capacity to 320MW.

- **Underground Conversions:**
  The Underground Utility District ("UUD") projects in this timeframe include the Raymond (FY23-26) and Mountain (FY23-25) UUDs. These major efforts will be capital intensive in FY24 thru FY27 years. Finally, the tier 3 fire threat mitigation projects at Florecita (FY26) and Canyon Close (FY27) projects are under consideration to underground existing overhead facilities in the area and will be scheduled after the above projects, if approved.

Table 3: Major CIP Projects for First Five Years of PDMP ($ Shown in Millions)

Project Name	FY23	FY24	FY25	FY26	FY27
Mobile Transformer	$0.2	$4.0	$0.1		
AMI Solution	$0.4	$2.1	$16.3	$22.0	
Fair Oaks Upgrades	$0.2	$5.0	$5.0	$0.0	
Path 3 Lines: Protection, Switchgear, and Cable Upgrades	$2.7	$5.8	$5.8	$2.7	$2.7
Path 2 Lines: Cable and Substructure Upgrades					$6.5
Phase Shifting Transformer				$0.1	$0.2
Series Reactors at TMG	$0.1	$0.1	$0.8	$1.4	$1.4
Underground Conversions	$0.3	$4.5	$6.3	$8.2	$8.7
Other Projects	$28.6	$28.3	$27.3	$24.9	$27.8

2.2. Second Five-Year Summary of Capital Improvement Projects

Building on the projects detailed in the first five years above, the FY2028 thru FY2032 include the implementation strategy that emphasizes on upgrading the subtransmission lines that transfers the power from east side of the City to the west side while ramping-up the implementation of improvements of other major projects. Figure 6 provides the recommended spending levels for the proposed CIP projects for each year from FY2028 through FY 2032.

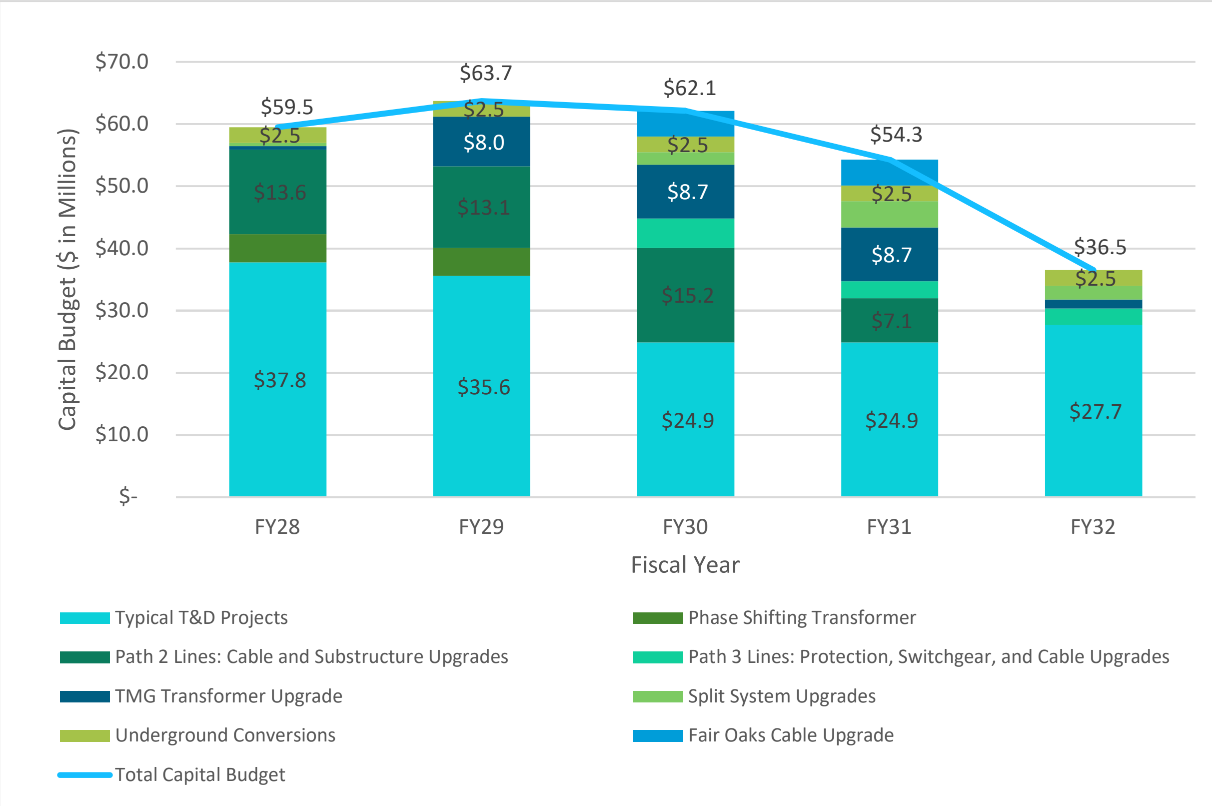


Figure 6: Breakdown of Master Plan Capital Budget for FY28-FY32 ($ in Millions)

The following is a discussion on the implementation of the major projects listed in Table 4 for the second five years of the PDMP:

- **Subtransmission Line Upgrades:**
  Upon completion of the Path 3 line and protection upgrades in FY2027, PWP will begin upgrading Path 2 lines, with an expected completion date in FY2031. This project will include:
  - Upgrading the Path 2 Lines cable, as well as their underground substructure system, to increase both their capacity and resiliency. Path 2 upgrade will help ensure resiliency and reliability of the power flow from east to west across town.
  - 35 kV switchgears will be installed on the remaining Path 3 line substations at Villa and Oak Knoll substations in FY2030-2032. These switchgears will provide operational flexibility and comprehensive protection systems to ensure robustness of Path 3 subtransmission lines.

  - 35 kV switchgear is planned for installation at the Fair Oaks substation in FY2030-2031 to introduce reliability improvements to the Fair Oaks substation.

- **Import Capacity Upgrades:**
  PWP will further work to improve its import capacity that will bring power into the city through the Phase Shifting transformer and TMG transformer upgrades.
  - Within the first five years, PWP expects to finish the LADWP interconnection project (phase shifting transformer) in FY2028.
  - Import Capacity Upgrades: PWP will first upgrade its three receiving station transformers at the TMG receiving station to increase the import capacity from the CAISO grid. This project will start in FY2028 and is scheduled to finish in FY2031. It will feature three new 220kV/35kV transformers as well as their associated protection systems.

- **Short Circuit Duty Limitation:**
  To further reduce the maximum available fault current on the 35 kV system to under 25,000 Amps, PWP will begin efforts in FY2030 to split the 35kV system into two systems, scheduled to complete in FY2032.

- **Underground Conversions:**
  PWP plans to continue establishing underground districts and undergrounding circuits at a rate of $2.5 million per year in FY2028-2032.

Table 4: Major CIP Projects for Second Five Years of PDMP ($ Shown in Millions)

Project Name	FY28	FY29	FY30	FY31	FY32
Phase Shifting Transformer	$4.5	$4.5			
Fair Oaks Cable Upgrades			$4.2	$4.2	
Path 2: Cable and Substructure Upgrades	$13.6	$13.1	$15.2	$7.1	
Path 3: Switchgear Upgrades			$4.7	$2.7	$2.7
Split System Upgrades	$0.5		$2.0	$4.3	$2.3
TMG Transformer Upgrades	$0.6	$8.0	$8.7	$8.7	$1.4
Underground Conversions	$2.5	$2.5	$2.5	$2.5	$2.5
Other Projects	$37.8	$35.6	$24.9	$24.9	$27.7

3. EXISTING ELECTRIC SYSTEM

This section provides an overview and a brief background of PWP's electric system, followed by descriptions of the generation, transmission, subtransmission, and distribution systems that allow PWP to deliver electricity to its customers.

3.1. Background and History

Pasadena Water and Power, a municipally owned and operated utility, delivers more than one million megawatt-hours ("MWh") of energy annually to over 67,500 residential and commercial customers within its 23 square-mile service territory, with a historical peak load of 320 MW.

For over a century, PWP has provided electricity to the residents and businesses in Pasadena through a safe, reliable, and cost effective power distribution system. PWP has assembled a portfolio of generating resources from a variety of different sources including large and small hydro, coal, nuclear, solar, gas, wind, geothermal, and landfill gas. Some of these resources are owned by PWP (e.g., the local Glenarm gas-fired units), but most are purchased under long-term contracts. In addition, PWP has ownership and contract rights on transmission lines, which are operated by the California Independent System Operator ("CAISO").

3.2. Description of Current Electric System

3.2.1. Local Generating Facilities

PWP has historically relied on its own local generation resources to provide a portion of its dependable supply of electricity to serve its customers. The Glenarm Power Plant has been keeping the lights on in Pasadena for more than 120 years. Over time, the generators have been retired, rebuilt, refurbished, and otherwise modified to take advantage of changing fuels and technologies used to generate electricity. Currently, PWP has five generating units at the Glenarm Power Plant as summarized in Table 5.

Figure 7: Pasadena Light & Power Station in 1903

Table 5: Summary of Local Generating Resources

Plant Name	Unit #	Unit Description	Operational State	Nameplate Capacity (MW)	Maximum Generating Capacity (MW)
Glenarm	1	Gas Turbine (Gas/Oil)	In Service	27	22
Glenarm	2	Gas Turbine (Gas/Oil)	In Service	27	22
Glenarm	3	Gas Turbine	In Service	47	44.8
Glenarm	4	Gas Turbine	In Service	47	42.4
Glenarm	5	Combined Cycle	In Service	76	65.8

Altogether, PWP can generate up to 197 MW of power from its Glenarm Power Plant for either reliability purposes, or to respond to CAISO requests to place units online to meet statewide energy needs. Alongside utility scale generation at the power plant, PWP customers are increasingly installing Photo Voltaic (“PV”) solar panel systems throughout the distribution system, with more than 2,100 systems installed to date. In recent years, customers started using battery storage technology to support their solar systems as the technology has become more reliable and cost-effective.

3.2.2. System Interconnections with Other Grids

PWP’s electric system is connected to both the CAISO-controlled transmission grid and the City of Los Angeles Department of Water and Power (“LADWP”) subtransmission network. The primary interconnection where PWP imports power to the City is through CAISO. Through these connections, PWP has access to electricity from a wide range of renewable energy resources (e.g. hydroelectric, solar and wind power), nuclear power, natural gas, and coal power.

PWP connects to the CAISO-controlled transmission grid at its TMG Receiving Station, located on the east side of Pasadena. This interconnection is made through the SCE transmission system at TMG, connecting PWP to the CAISO grid with two overhead lines operated at 230 kV. These lines provide the majority of the City’s energy needs throughout the year, where power is purchased on the CAISO market, generally a lower cost than the cost of producing power at the Glenarm Power Plant. PWP has a contract with SCE to import up to 336 MW at TMG.

PWP originally connected to LADWP in 1917 via two 35 kV subtransmission lines. PWP continued to use this connection until 1971, when PWP initiated an interconnection to SCE at TMG. Today, PWP only uses the connection with LADWP in the event of an emergency where the intertie with SCE cannot be maintained. This connection would mainly be used as a source to “black-start” the power plant in the case that the connection with SCE is lost at TMG. PWP is considering using these lines to keep customers in service during CAISO ordered load curtailment (rolling blackouts) events when there is a power shortage on the bulk power system. Under normal circumstances, due to a difference in power phase angle and restrictions related to connecting two Balancing Authorities (CAISO and LADWP), the connections with SCE and LADWP cannot be operated at the same time. PWP can import up to 40MW in total between these two lines.

3.2.3. Subtransmission System

Power is imported into PWP’s system using three 220 kV/34.4 kV transformers at TMG Receiving Station as well as five local generators at the Glenarm Power Plant delivering power to the Glenarm Receiving Station. The power is then distributed throughout the City to different substations and receiving stations over a 35 kV network of underground subtransmission system.

PWP relies on its 36 subtransmission lines to deliver power from the three receiving stations across the city to all of its distribution substations. These lines include the “Path 1” lines which transfer power from TMG to Santa Anita, the “Path 2” lines which transfer power from Santa Anita to Glenarm, the “Path 3” lines which transfer power from Santa Anita Receiving Station to Villa, Chester, and Oak Knoll substations, and then to the Glenarm Receiving Station. Finally, there are the “Load Lines” which transfer power from receiving stations to distribution substations. PWP also has 16.8 miles of overhead 35 kV lines (St Johns subtransmission lines), which connect the Glenarm Receiving Station to LADWP’s Receiving Station A, located in downtown Los Angeles.

3.2.4. Distribution Substations

PWP has 11 distribution substations, of which 10 are served by 35 kV subtransmission lines, and one substation served by 17 kV distribution lines. A distribution substation is a neighborhood station that transforms the 35 kV sub transmission voltage to either 17 kV or 4 kV to be distributed through circuits to customers. At these distribution substations, there are a total of 25 unit substations. Each unit substation consists of a double-ended design with two transformers and a connecting switchgear in between, as shown in Figures 5 and 6. Table 6 shows a summary of total transformer units and distribution feeders.

Table 6: Summary of Distribution Substation Units and Feeders

	17 kV		4 kV		Totals	
Substation Name	No. Transformer Units	No. Distribution Feeders	No. Transformer Units	No. Distribution Feeders	No. Transformer Units	No. Distribution Feeders
Brookside	-	-	1	2	1	2
Chester	2	6	1	4	3	10
Del Mar	1	4	2	8	3	12
Eastern	1	3	1	4	2	7
Fair Oaks	3	12	-	-	3	12
Glenarm	2	11	2	8	4	19
Hastings	½	2	1	4	1 ½	6
Oak Knoll	2	8	-	-	2	8
Villa	2	12	-	-	2	12
Santa Anita	1	9	2	8	3	17
Wilson	-	-	1	4	1	4

The tie-breakers within each unit substation's switchgear have the ability to automatically transfer the entire unit substation load onto one of the transformers should the other fail. This is a very reliable design that provides exceptional operating flexibility.

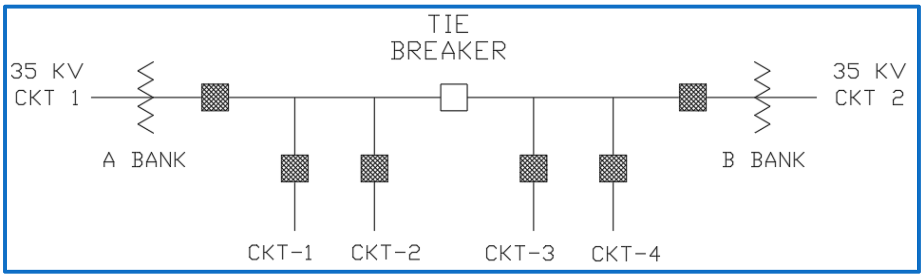


Figure 8: Typical Substation Unit Design One-Line Diagram

The 35 kV subtransmission lines are connected to the unit substation transformers through 5-way and/or 4-way SF6-insulated 35 kV switches. These switches are manually operated and used to isolate a unit substation or its transformer, as well as tie multiple 35 kV lines together. This is beneficial for both maintenance purposes as well as for emergencies when additional 35 kV subtransmission capacity is needed. A typical distribution substation design is shown in Figure 6.

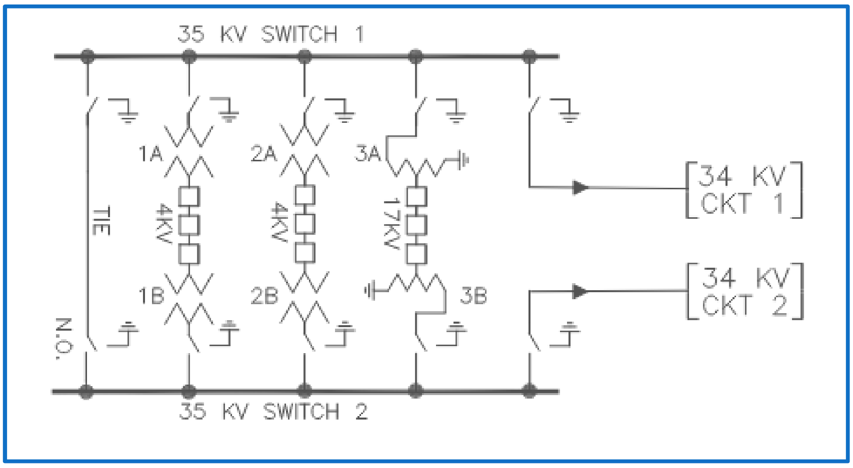


Figure 9: Typical Distribution Substation Design One-Line Diagram

3.2.5. Protection and Control Systems

A large number of PWP's system protection and control devices are vintage electromechanical relays and analog controls. The equipment and systems still used by PWP are not unusual, and are typical of most electrical utilities that are in the process of upgrading to modern substation control systems and digital protective devices. While the electromechanical relays are routinely tested and maintained, they are becoming increasingly difficult and expensive to maintain because of the diminishing number of manufacturers that have spare parts available. PWP has established a program to replace all of these outdated devices.

Recognizing the need to modernize, PWP is in the continual process of upgrading its SCADA system to improve the situation. Through SCADA, power dispatchers can monitor the power flow and voltages on all of its distribution feeders, substation transformers, and 35 kV subtransmission circuit breakers. The SCADA system also allows dispatchers to remotely operate high voltage equipment, which helps to increase workforce safety and efficiency, and reduce outage times.

3.2.6. Medium-Voltage Capacitor Banks

In PWP's system, reactive power is mainly generated from capacitor banks, local generators at the power plant, and the underground cables. Reactive power supply is necessary to maintain acceptable voltage levels across the system. Reactive power can be imported into the PWP system from the CAISO interconnection at TMG, and is contractually limited between 0.97 lagging power factor to 0.99 leading power factor. PWP dispatchers utilize the

Figure 10: 35kV Capacitor Banks at Santa Anita Receiving Station

local generators at the power plant and the receiving station capacitor banks to regulate the reactive power flow throughout the system, and to avoid fines from violating the CAISO limits.

PWP's electric system has enough capacity to serve the reactive power load of the City, including maintaining a reserve margin to account for the loss of its single largest source of reactive power. Moving forward, as PWP adds new bulk power resources to the subtransmission systems, such as a bulk power battery or a phase shifting transformer, PWP will assess the additional reactive power demand of the system. Additional 35kV capacitor may be needed to support these individual projects, and will be considered as a part of each project.

3.2.7. Distribution System

PWP's electric distribution system is comprised of a combination of Overhead ("OH") conductors and Underground ("UG") cables, operating at either 4 kV or 17 kV. Overall, the City has (64) 4 kV distribution circuits and (55) 17 kV distribution circuits that extend out of the 11 distribution substations.

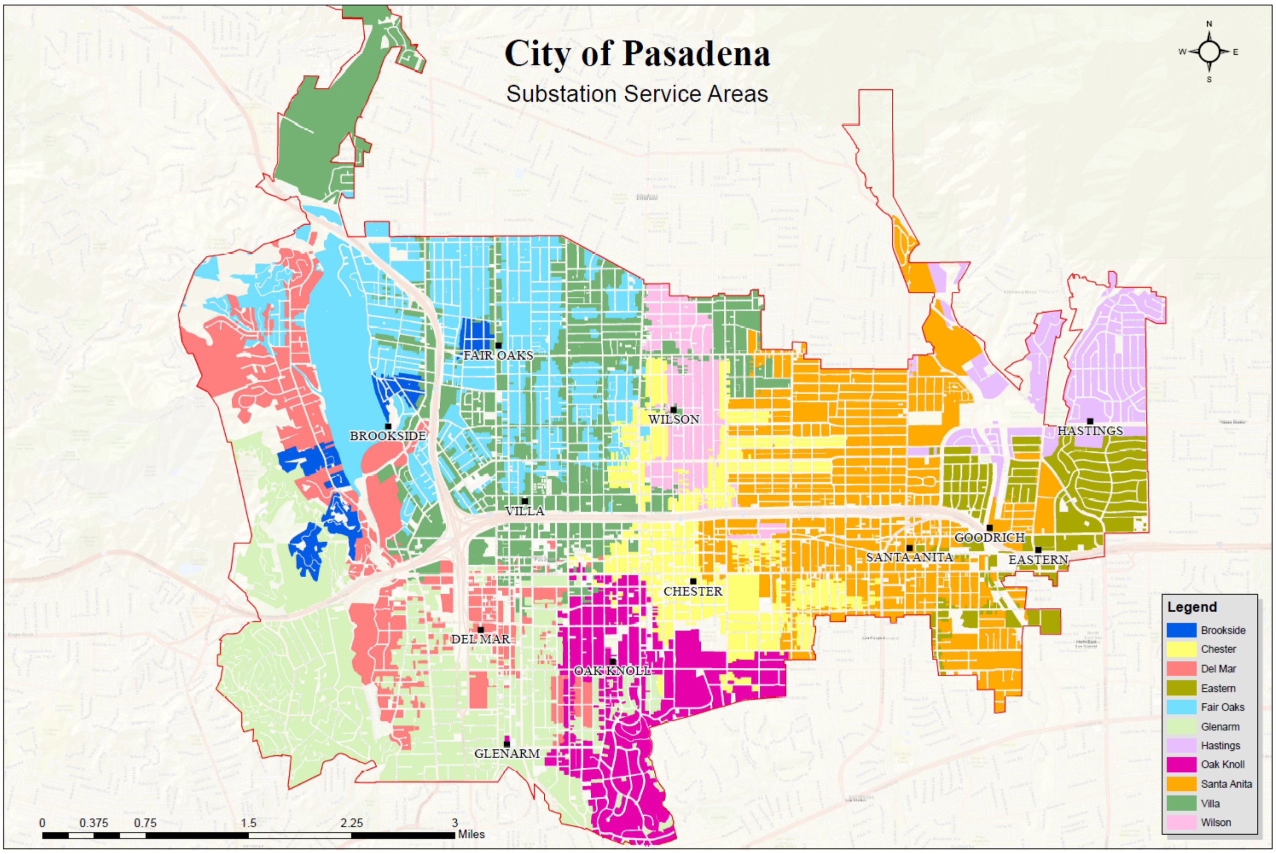


Figure 11: PWP's Substation Service Areas

A summary of PWP's distribution system equipment such as distribution transformers, switches, and Circuit Miles of primary conductor is shown in Table 7.

Table 7: Summary of Distribution System Equipment

		17 kV		4 kV		Totals	
Asset Type	**Unit of Measure**	**OH**	**UG**	**OH**	**UG**	**OH**	**UG**
Primary Conductor	Circuit Mile	34	364	133	34	167	500
Secondary Conductor	Circuit Mile	116	411	305	76	421	487
Transformers	Unit	597	5,027	2,110	694	2,707	5,721
Switches	Unit	43	656	507	334	550	990
Power Poles	Unit	-	-	-	-	11,076	-
Vaults / Manholes / Pull Boxes	Unit	-	-	-	-	-	7,748
Capacitors	Unit	-	-	35	-	35	-
Fault Indicators (FI)	Unit	91	816	106	239	203	1055
Reclosers	Unit	1	2	3	8	4	10
Resettable Fault Interrupters (RFI)	Unit	-	191	-	1	-	192

4. ELECTRICITY DEMAND AND LOAD PROJECTIONS

A load forecast is used by electric utilities to estimate future load of the system for planning and resource adequacy purposes to ensure that the utility can effectively serve customer demand. The annual load forecast needs to be adjusted to meet the needs of the evolving grid and changes to customers' energy usage behavior. This forecast will be used to determine the needs for the distribution and transmission systems to provide safe, high quality, and reliable service.

The total system-wide electricity demand is a forecast based on historical usage, the relationship between temperature and maximum demand, as well as growth predictions of factors such as the electrification of buildings and vehicles, and DER proliferation. The forecast is then broken down to each distribution circuit level for proper planning of the size and number of distribution circuits, transformers, substations, subtransmission lines, and sources of power to serve the City.

The following is a brief summary of the factors that contribute to the demand forecast for the next 20 years, such as energy efficiency programs, transportation and building electrification, new customer loads/upgrades, and DER penetration.

4.1. Historical Demand Summary

PWP delivered approximately 1,017 Gigawatt-hours ("GWh") of energy in calendar year 2020 meeting a peak demand of 297 MW. PWP registered its historical peak demand of 320 MW in 2010. Figures 12 and 13 show the actual energy sales and system peak demands for calendar years between 2010 through 2021, respectively.

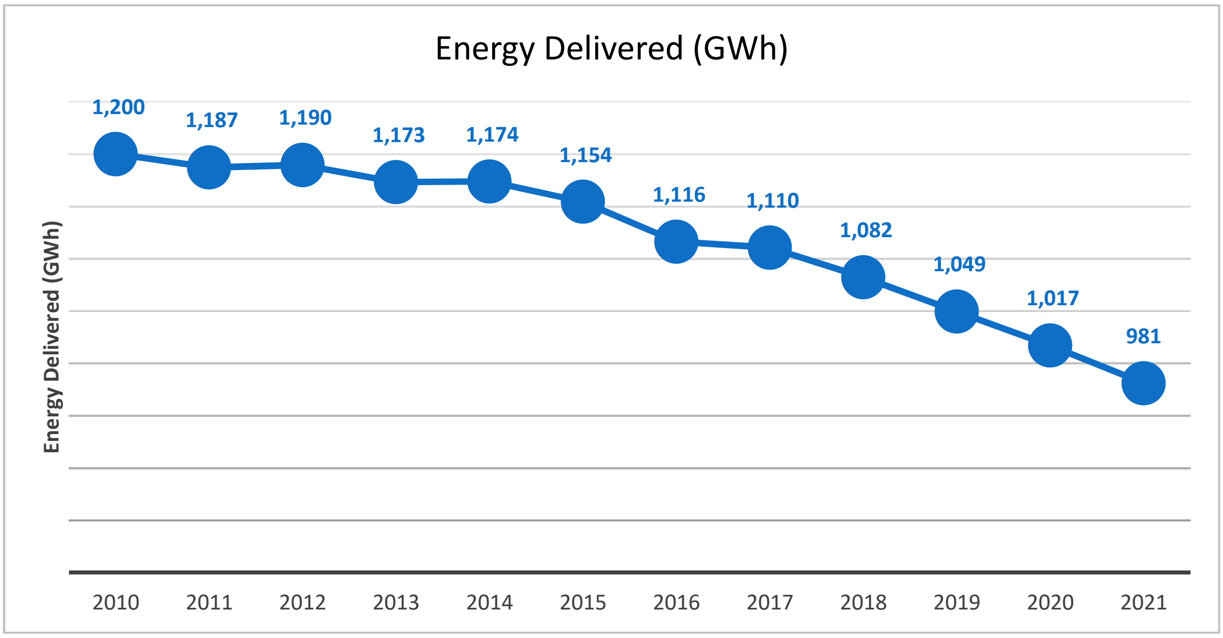


Figure 12: Historical Energy Delivered in MWh by PWP System (2010-2021)

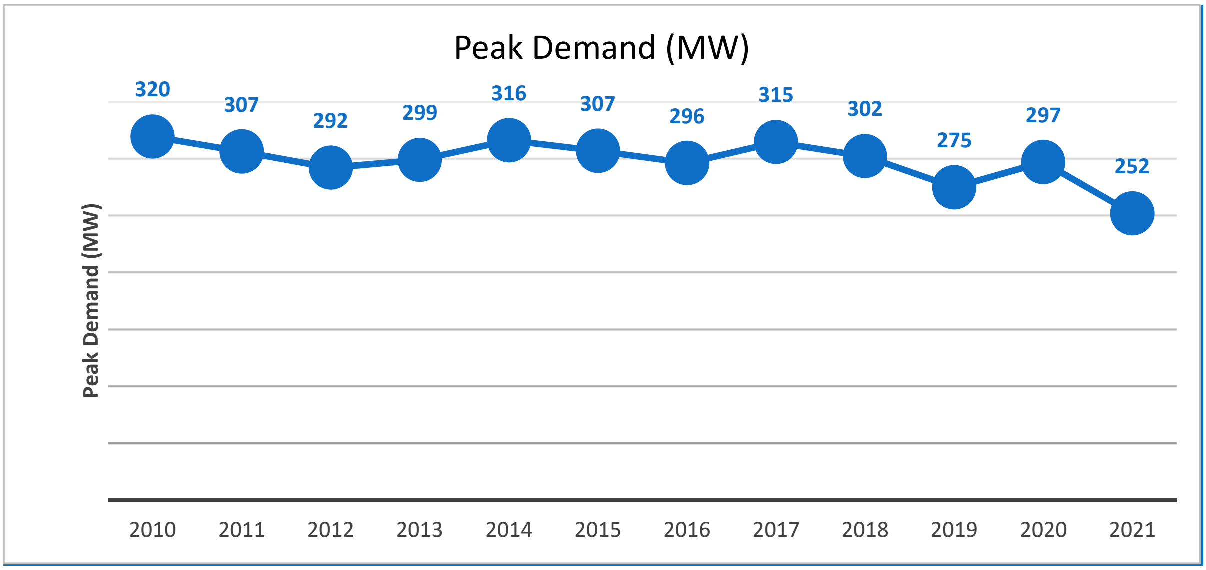


Figure 13: Historical System Load Peak Demand (2010-2021)

4.2. Driving Factors of the Load Forecast

4.2.1. Distributed Energy Resources

In the past 10 years, PWP residential and commercial customers have installed more than 2,100 Rooftop Solar Panel systems. By the end calendar year 2020, the combined nameplate power of approved systems is greater than 19 MWs. Recently, PWP customers have started to install battery storage ("BESS") capabilities to their PV systems, with approximately 10% of the new solar systems now having battery systems. This trend is expected to grow over the coming years as the price of PV and battery storage systems decrease and depending on programs and incentives offered by the City and/or the State.

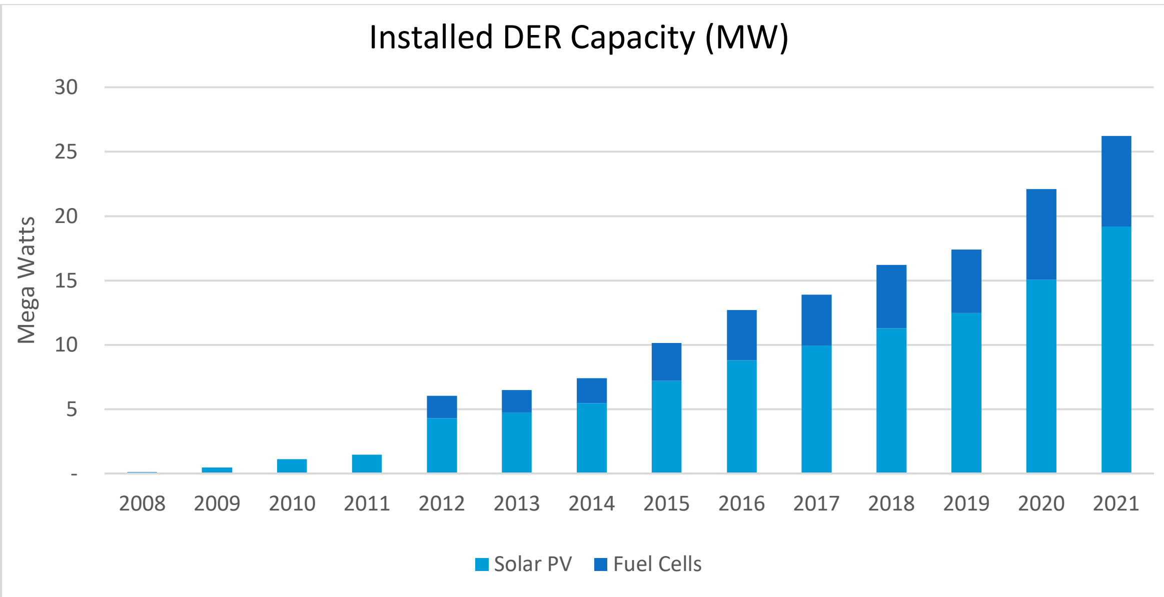


Figure 14: Installed DER Capacity

The rate of PV installations by customers is directly related to the Net Energy Metering (“NEM”) rates set by the utility and state, which help to incentivize customers to adopt solar generation. This NEM program is implemented by the California Public Utilities Commission (“CPUC”) and imposed on Investor Owned Utilities (“IOU”), but is widely followed by Municipal Owned Utilities (“MOU”) like PWP. The current NEM rates are set to remain in place until the total capacity of customer installed PV’s exceeds 5% of peak system load, or approximately 15 MW for PWP’s system. This limit will be reached soon and will lead to a new rate structure for DERs, informally called NEM 2.0.

PV and BESS growth rate will be reevaluated and considered in future revisions of the Integrated Resource Plan (“IRP”) to account for any factors that may raise or lower the initial rates. These factors include new rebates/NEM rates that become available to customers, or market conditions that drive the price of solar/storage options either up or down.

4.2.2. Transportation Electrification

Electric Vehicles (“EV”) are growing in popularity and becoming viable alternatives to traditional gasoline-powered transportation options. EVs require a comprehensive grid of charging stations, both at customers' homes, workplace, and at public sites, to ensure their feasibility for most customers’ use cases. PWP is leading the charge in this regard, offering rebates to customers who purchase EVs within the City, as well as investing in large scale charging stations for residents, Pasadena workers, and commuters to charge their vehicles using the PWP grid. This combination of the growth of at-home charging and various charging plazas across the City will play a key role in increasing the electricity usage (“MWh”) on the system.

Figure 15: Pasadena's Marengo EV Charging Plaza

The key to an effective transportation electrification program is ensuring EVs charging is done at the right time. To date, residential EV charging is typically 80% at home and 80% of that is off peak. In general, very few infrastructure upgrades are currently needed for home charging. If PWP has the ability to sell more power with minimal upgrades, that creates a downward pressure on rates for all PWP customers.

Charging plazas can present the utility an opportunity for large spot loads throughout the City, which will potentially raise the effective capacity requirements on the subtransmission and distribution system. In the past few years, PWP has started commissioning and completing various electric charging plaza projects, and foresees this trend to continue.

4.2.3. Building Electrification

According to California Building Energy Efficiency Standard - Title 24, all new construction of low-rise residential buildings must incorporate the option for electrification, and renovations of existing residences will be guided by energy efficiency parameters. The three main household appliances that can be converted from gas to electric powered options are stove ranges, space heaters, and water heaters. An average of one kW per each new living space/building installation is considered by PWP in new service connections.

Pasadena has more than 40,500 customers currently using natural gas. The load forecast projection takes into account the goals set by California Clean Energy and Pollution Reduction Act - SB 350 to assess their impact on load and energy consumption. SB 350 establishes goals to reduce greenhouse gases ("GHG") emissions of 40% by 2030 and 80% by 2050. These goals may be passed down to the consumer through potential rebate programs in the future.

4.2.4. Energy Efficiency Program

Since 2006, PWP has collaborated with its neighboring Southern California Public Power Authority ("SCPPA") members on developing energy efficiency programs and reporting related results for peak and annual savings. This report uses historical data from PWP's Annual Energy Efficiency Reports to project future energy efficiency.

4.3. Net Load Forecast

The impact of transportation electrification, energy efficiency, building electrification, and DER penetration on the base load is expected to span over the next 20 years. The retail and system load used take into account historical usage, coupled with planned (or reduced) load in the near future, and an in depth review of energy efficiency and load offsets due to PV installations. These forecasts are also weather-normalized projections. The current projection is that PWP electric systems load can grow to about 340 MW demand by the year 2042. PWP is currently in the process of updating its Integrated Resource Plan ("IRP"), which will provide updated projections for load and energy usage forecasts.

The peak load in 2020 was approximately 297 MW, which is very near the 5-year average annual peak load of 301 MW. The resulting net load forecast is displayed in Figure 12.

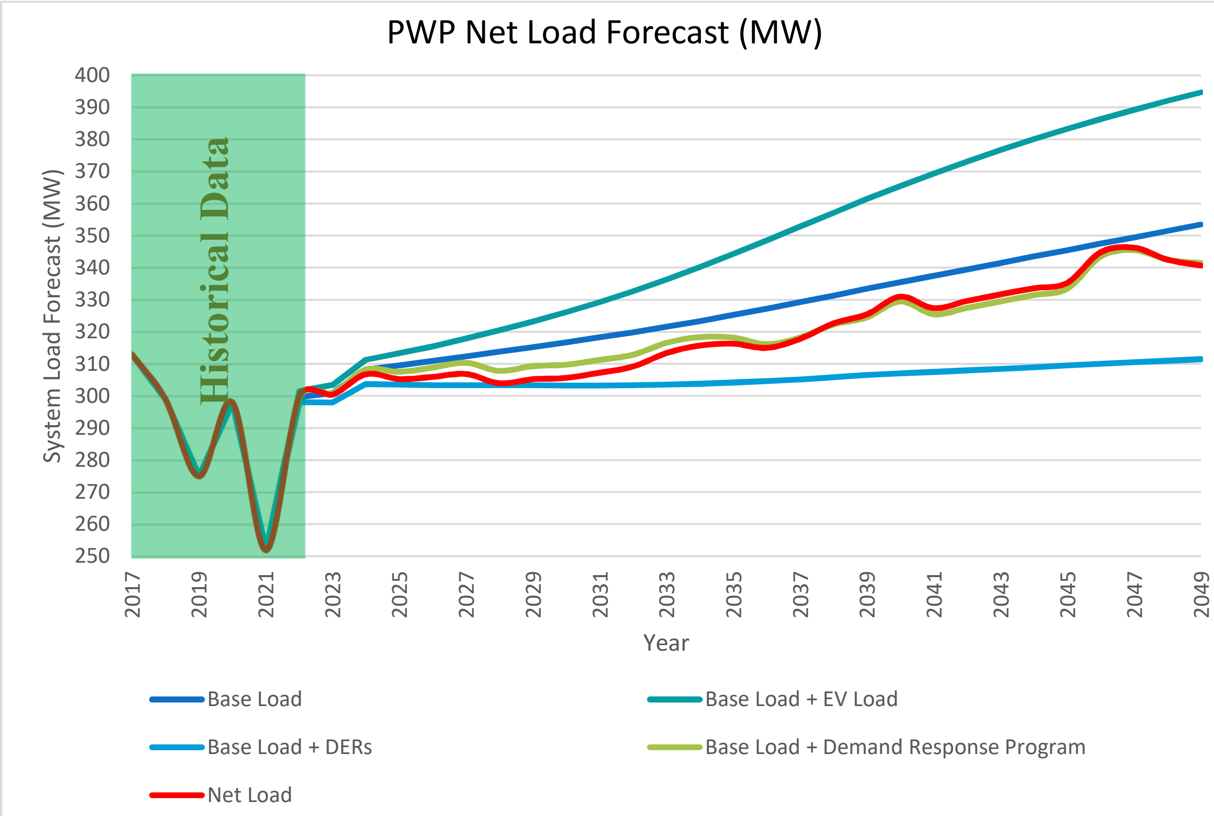


Figure 16: System Peak Load Forecast (MW)

5. SYSTEM PLANNING AND RELIABILITY CRITERIA

Continuous planning and assessment of the electric system is necessary so that PWP can determine the most cost-effective investments to improve the electric system, and ensure that it can handle forecasted system loads. In the coming years, smart grid technologies such as AMI, Distribution Management System ("DMS"), SCADA, DERs, EVs, and building electrification will all play a role in the reliability and operation of PWP's power grid. They will require PWP to manage and plan the implementation of these new technologies with extra care to ensure a safe and sustainable grid.

5.1. System Planning Process

The purpose of system planning is to periodically identify internal and external factors that may influence system performance, and evaluate their impacts on system reliability and power quality. This process is guided by priorities of maintaining safety for the public and City employees, ensuring system reliability, and providing services at reasonable rates. Figure 17 shows PWP's annual planning process used to evaluate the current system's performance.

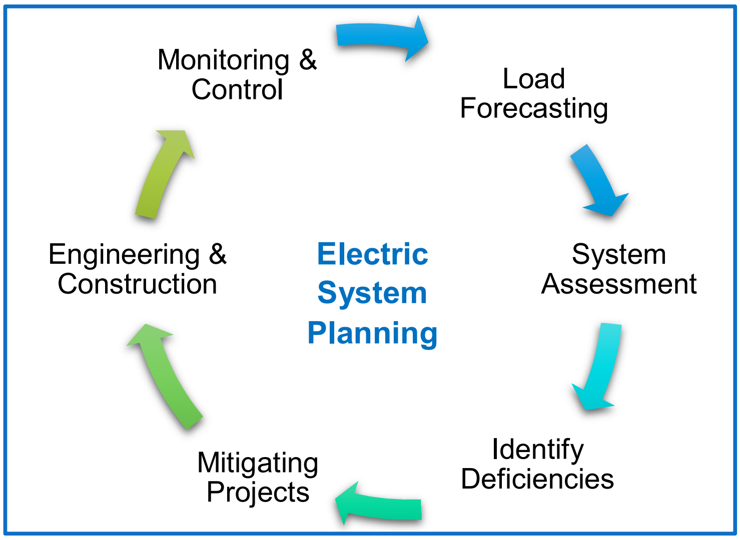


Figure 17: Power System Planning Process

Load forecasts are reviewed annually to update load predictions with current data for more accurate projections. In the future, PWP will be able to leverage the vast amount of load data from the future AMI and DMS systems to improve the forecast. After the annual load forecast is complete, staff conducts annual power-quality and load flow studies on the distribution system, analyzing the distribution and subtransmission systems to identify equipment concerns which may experience overloading or low voltage issues. It then recommends both maintenance and capital projects to mitigate these issues. The initial five-year CIP plan developed as part of the PDMP will be reviewed and adjusted annually based on revised load forecasts and system assessments.

Key system limitations that will be addressed in mitigating projects include equipment fault current rating violations, equipment capacity issues during high loading conditions, and customer voltage/power quality issues.

The traditional approach to addressing system growth has been to upgrade, replace, or add more utility infrastructure. However, in the coming years, grid modernization is expected to provide PWP with much more useful data that will allow for different solutions in efforts to solve system problems and limitations. Non-traditional solutions may include demand management programs, and more rate options with the new Customer Information System ("CIS") system using the improved customer metering through AMI, energy efficiency programs, utility owned DER deployments (such as BESS and smart customer solar inverters), and potentially DER incentives for customers.

5.2. System Planning Criteria

The criteria below are used to evaluate how well the system is designed for a given operating scenario, and should be periodically updated to consider new equipment and technologies.

5.2.1. Distribution Planning and Reliability Criteria

PWP designs, maintains, and operates its electric distribution system to meet the voltage level requirements of Range A of ANSI Standard C84.1-2016. The optimum utilization of the Load Tap Changer ("LTC") Voltage Regulators on substation transformers are vital to meet these requirements. The voltage limits (on a 120 V base) for the distribution system, as well as recommendations for maximum loading, power quality, and number of customers per circuit are shown in the Tables 8 – 11.

Table 8: Allowable Voltage Levels for Distribution System Design

Parameters	Minimum	Maximum
Service Voltage at Customer Meter (Normal Operation)	114V	126V
Service Voltage at Customer Meter (Emergency Operation)	110V	128V

Table 9: Allowable Loading Levels for Various Distribution System Components

Parameters	Maximum Loading Levels
Conductor Loading (Rated Thermal Capacity)	125% (4 Hour Limit)
Distribution Transformers in Fire Hazard Zone	100%
Overhead Distribution Transformers	150%
Underground Distribution Transformers	135%
Conductor Loading Imbalance (Phase Current to Average Current Among Phases)	+/- 15%

Table 10: Allowable Power Quality Levels for Distribution System Components

Parameters	Minimum	Maximum
Feeder Power Factor	92%	100%
Maximum Flicker		5%
Individual Harmonic Distortion for each component		3%
Total Harmonics Distortion of all Equipment on line		5%
PV Inverter Voltage Ride-Through	114V	126V
PV Inverter Frequency Ride-Through	59.5Hz	60.5Hz

Table 11: Recommended Maximum Customer Count per Distribution Circuit and/or Isolating Device

Circuit Voltage	Customers per Circuit	Customers per Isolating Device
4 kV	400	150
17 kV	1,600	500

5.2.2. Subtransmission System Planning and Reliability Criteria

PWP designs and operates its subtransmission system per Range A of ANSI Standard C84.1-2016. Tables 12 and 13 shows the operating limits of the subtransmission lines' voltage and loading under normal and emergency conditions.

Table 12: Allowable Voltage Levels for Sub-transmission System Design

Subtransmission Lines	Voltage Levels	
	Regulation %	Base Voltage
Normal Operating Voltage	+/- 5%	34.5 kV

Table 13: Allowable Current Loading Levels for Sub-transmission System Design

Component Loading (OH & UG)	Loading Levels (%)	
	Normal	Emergency
Conductor Loading % (Conductor Rated Thermal Capacity)	100%	125% (4 Hours Limit)

5.2.3. Substation System Planning and Reliability Criteria

PWP will consider standardizing on one size of power transformer for future replacement of substation units which will save resources during the planning, design, and the procurement processes. The capacity of each transformer will be determined based on PWP's needs. Substations be designed and operated to meet the voltage level requirements of Range A, per ANSI C84.1-2016.

Table 14: Allowable Loading Levels for Substation Transformers Design

Component Loading	Loading Levels (%)	
	Normal	Emergency
Substation Transformer Loading %	62.5%	125%
Receiving station Transformer Loading %	62.5%	125%

6. ELECTRIC SYSTEM RELIABILITY

The reliability of PWP's electric system is critical to the City's economic vitality and the well-being of the Pasadena community. To maintain the high service reliability it offers to its customers, PWP continuously conducts studies to improve reliability performance data and metrics, evaluate trends and their economic significance to PWP customers, and promote the applications of reliability-value based planning.

6.1. Reliability Indices

PWP regularly conducts comprehensive reliability analyses to identify common causes of outages in the system and potential means to reduce the frequency and duration of outages in the future. Historical outage data such as frequency and duration of interruptions is used to track the reliability of the electric system. Momentary outages (less than 5 minutes in duration), planned, and customer-caused outages are not considered in the indices.

The major two indices used to quantify electric utility reliability are the System Average Interruption Frequency Index ("SAIFI") and the System Average Interruption Duration Index ("SAIDI"), which can be defined as:

SAIFI quantifies how often the average customer experiences a sustained interruption over a one year period.

$$SAIFI = \frac{\sum Customers\ Interrupted}{Total\ number\ of\ customers\ in\ the\ system}$$

SAIDI quantifies the average duration of an interruption for an average customer over a one year period.

$$SAIDI = \frac{\sum Customer\ Minutes\ of\ Interruption}{Total\ number\ of\ customers\ in\ the\ system}$$

Table 15 shows the goals PWP has set for itself for both the SAID and SAIFI indices.

Table 15 : Reliability Indices Goals

	SAIDI	SAIFI
Combined Outages	50.0	0.41
Unplanned Outages	35.0	0.31
Planned Outages	15.0	0.10

For the calendar years 2017 to 2021, the system reliability indices were calculated based on the total number of customers affected and the total number of customer interruption minutes. Figures 18 and 19 shows the SAIDI and SAIFI indicators, respectively, for PWP over the past five years. As noted in the chart, there were a higher number of customer interruptions in 2020. This was impacted by an increase in customers staying home as a result of COVID-19 pandemic driven state orders, combined with extended heatwaves during the summer, which caused residential feeders to experience higher load than normal.

The figures below show that both SAIDI and SAIFI indices are stable (lower is preferred) after discounting 2020 as an outlier because of the "stay at home orders" put in place.

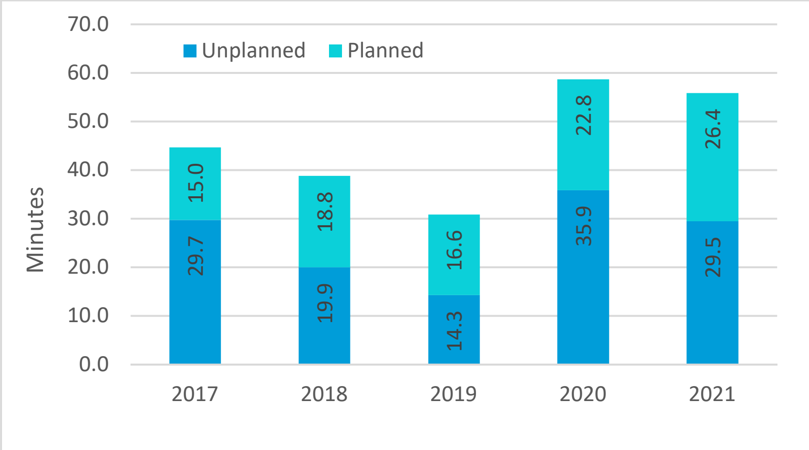


Figure 19: System Average Interruption Duration Index (SAIDI)

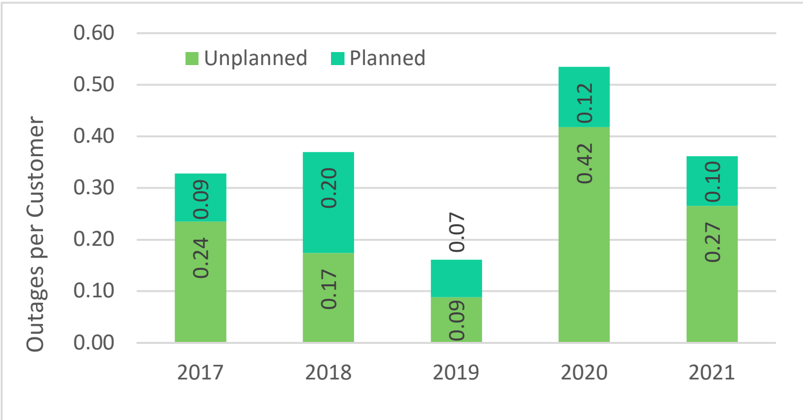


Figure 18: System Average Interruption Frequency Index (SAIFI)

While PWP's reliability is exceptional compared to similar sized utilities, it can improve the SAIDI index for unplanned outages by increasing the speed of identifying the location of an outage, particularly across the underground distribution system. Implementing AMI and upgrading the existing OMS system will drastically improve PWP's ability to identify the scope and location of different outages.

Figure 20 shows the number of sustained interruptions in the past six years. Generally, the number of both planned and unplanned outages are declining due to continual improvements made on the distribution system.

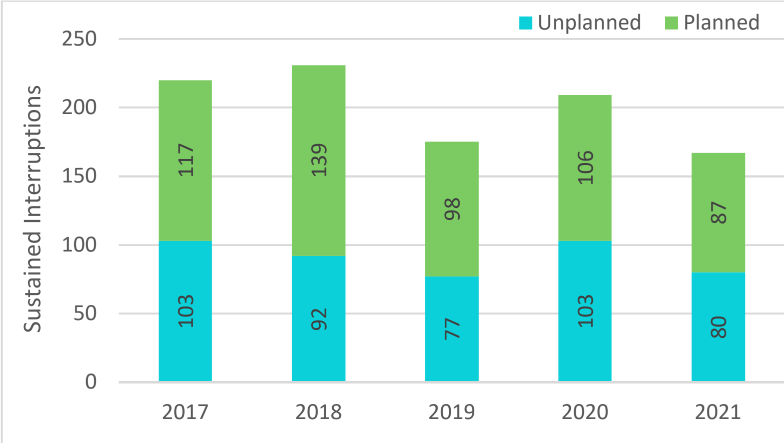


Figure 20: Number of Outages

The unplanned outages will primarily be addressed through a comprehensive, risk-based asset replacement program, and through the protection and automation program. As PWP replaces its aging assets with new assets, it will focus on installing new technologies that will support remote switching, increased employee safety, and the ability to avoid planned outages during maintenance work. Planned outages can also be reduced by improved switching practices (like switching underground H&J switches energized) and hot stick practices for overhead distribution.

Table 16 compares the number of unplanned outages per circuit mile of the overhead ("OH") and underground ("UG") systems for the last five years.

Table 16: Overhead vs. Underground Outages per Circuit Mile

Calendar Year	Overhead Outages/Circuit Mile	Underground Outages/Circuit Mile	Ratio of Outages (OH/UG)
2017	0.40	0.05	7.46
2018	0.36	0.05	7.78
2019	0.32	0.03	9.36
2020	0.35	0.07	5.24
2021	0.30	0.04	7.15
System Average	**0.35**	**0.05**	**7.40**

The number of outages per circuit mile on the overhead system are clearly higher than the underground system on average (7.4:1). The main reason for this ratio is that the overhead system has a greater exposure to external outage contributors (such as trees, palm fronds, and animals) compared to the underground system. PWP plans to improve this indicator by proactively replacing aging overhead assets, improving its vegetation management program, performing a more frequent and detailed inspections, and continuing the undergrounding program.

6.2. Root Cause Analysis

PWP continually performs a root-cause analysis for circuit outages to evaluate possible corrective measures to improve reliability. These corrective measures include proactively replacing equipment with high probability of failure, voltage conversions for 4 kV circuits to operate at 17 kV, converting overhead circuits to underground, and installing coordinated protective devices to mitigate the scope and duration of future outages.

Table 17 provides a breakdown of unplanned outages per cause over the past three years. The failure of aging overhead and underground equipment contributed to more than 50% of the unplanned outages in the last three years, with a majority of those outages being overhead equipment failures. PWP has been ramping up its replacement programs to effectively reduce these unplanned outages. A dedicated tree trimming program is directed to help mitigate outages caused by overgrown trees encroaching the high voltage lines, which cause outages when tree branches/palm fronds come into contact with overhead wires. Furthermore, converting overhead 4 kV circuits to operate at 17 kV will help reduce exposure to faults caused by trees, animals, and wind by increasing the space between overhead conductors, as well as facilitating the replacement of aging equipment with new equipment.

Table 17: Count of Unplanned Outages per Outage Causes (2019-2021)

Outage Cause	Outage Count	% of Total
Overhead Equipment Failure	73	28.1%
Underground Equipment Failure	56	21.5%
Trees/Palm Fronds	47	18.1%
Squirrel/Rodent	13	5.0%
Cause unknown	11	4.2%
Customer Equipment Failure	11	4.2%
Extreme Weather Conditions	8	3.1%
Overhead Equipment Overloading	8	3.1%
Human Error	7	2.7%
Mylar Balloons	7	2.7%
Bird	6	2.3%
Motor Vehicle	5	1.9%
Dig-In	2	0.8%
Substation Equipment Failure	2	0.8%
Crew Requested Outage	1	0.4%
Fire	1	0.4%
Foreign Objects	1	0.4%
Underground Equipment Overloading	1	0.4%
Grand Total	**260**	**100.0%**

7. ELECTRIC SYSTEM ASSETS

PWP assessed the current conditions and capabilities of the existing system components to develop a 20-year Master Plan of capital projects to ensure a safe, reliable, and cost-effective electric system to its customers.

7.1. Criticality, Health, and Risk Analysis

An important part of a functional asset management system and replacement program is the methodology selected to rate components by their risk to system reliability.

PWP calculates a components risk by assessing its criticality to the system, as well as the component's relative health. Both of these metrics feed into a risk calculation, which identifies the components that are more likely to fail, and which would cause the highest impact to the system and the community. The analysis considers testing and inspection data, as well as general attribute data for each asset, and generates a unique score for prioritizing its replacement.

Because of limitations on the amount of source data available, PWP only considers the following equipment for risk analysis: substation transformers, circuit breakers, distribution transformers and switches, poles, vaults, and underground cables. Risk assessments can be applied to any component in the system, but only if sufficient accurate data is available.

Finally, the Risk Index for each individual asset is calculated, as follows:

$$Risk\ Index_{asset} = Criticality\ Index_{asset} * Health\ Index_{asset}$$

Assets with the highest risk index score will be prioritized for replacement. Finally, the replacement rates and schedules need to be defined to create the annual Capital Improvement Program. It is assumed that the current average risk of components in all asset categories is sufficient to maintain current reliability. It is further assumed that the overall risk of failure directly correlates to the SAIDI and SAIFI indices. This replacement strategy identifies the required number of asset replacements in each asset category that would be needed to maintain the current level of risk. This risk level is assumed to be intrinsically linked with reliability. This risk assessment identifies the required number of asset replacements in each asset category needed to maintain the current system reliability.

7.2. Evaluation of Subtransmission System

The average age of all PWP's electric equipment currently installed today is over 30 years old. Generally, the industry accepted useful life for electrical equipment ranges from 30 to 50 years. Certain equipment in PWP's system are past their rated useful life, one example being the 18 substation power transformers that are more than 60 years old.

Equipment may need to be replaced sooner than their rated useful life depending on their criticality and respective operating conditions, or sometimes much later. When subtransmission and distribution equipment fails unexpectedly, it poses risks to PWP personnel and public safety, reduces system reliability, inconveniences customers, and increases the cost of operations. For these reasons, PWP places a heavy focus on avoiding unplanned equipment failures through proactive maintenance and replacements when necessary.

7.2.1. Underground Vaults and Conduits

PWP has approximately 268 subtransmission vaults, of which three vaults need immediate refurbishment or replacement. The vaults are deteriorating due to a chemical used in the concrete mix, which is a common issue for utilities that have underground vaults. This can cause damage to equipment in the vaults, be a safety hazard to personnel, and reduce the vaults' ability to support traffic loads. PWP plans to either refurbish the deteriorated vaults or replace them entirely with new vaults.

All of PWP 35 kV circuits within the City boundaries have been installed in a dedicated underground conduit system that interconnects all of PWP substations through underground vaults. This conduit system is also aging, and poses a concern when replacing subtransmission cables. There are over 41 miles of subtransmission system conduit banks installed throughout the City. Most of the conduit system is filled, with no spare conduits available. The lack of spare conduits makes it difficult for PWP to upgrade, add, or replace subtransmission lines, requiring the removal of the existing cable first before PWP can install a new cable. This is inefficient and impacts system reliability, where single line outages can potentially take much longer to restore because of the time it takes to replace the cable. PWP will evaluate the needs of the conduit system for the subtransmission system on a case-by-case basis when upgrading cable.

Figure 21: Underground 35kV Subtransmission Lines (Path 2)

7.2.2. Underground Subtransmission Cables

PWP operates its 35 kV subtransmission network to connect each of the receiving stations and substations. This network contains over 100 miles of installed 3-phase cable, which consists of various insulation types, conductor sizes, and ages.

The following factors were considered to evaluate the priority of replacing/upgrading the subtransmission cables: age, installation environment, insulation material, operating history, loading history, failure history, capacity requirement, and estimates of remaining life through testing.

PWP's subtransmission cables are insulated using either solid dielectric cross-linked polyethylene ("XLPE"), or ethyl propylene rubber ("EPR"), or are the much older vintage paper-insulated lead cable ("PILC").

The expected useful life of PWP's medium-voltage solid dielectric cable installed in the conduits are between 40 and 50 years. Figure 18 shows the breakdown of the 35 kV cable lengths by age group. About 71% of the 35 kV cables have already reached the typical end of its useful life and about 14% more will reach this mark in the next 10 years.

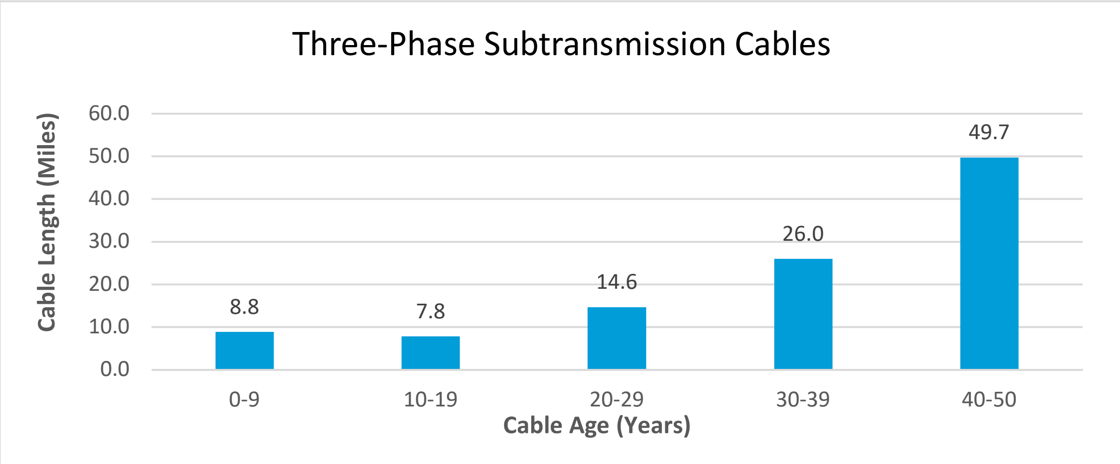


Figure 22: Length and Age of the 35 kV 3-Phase Subtransmission Cables

Generally most underground circuit failures occur at the splice and termination points, and not in the cable itself. The failure of cable insulation is a very strong indicator that the entire length of cable should be replaced, and that more failures will follow at an exponentially increasing rate.

As a part of this Master Plan, PWP has determined that it is going to replace on average about one 35 kV circuit per year to increase system capacity and maintain system reliability.

PWP plans to replace the major subtransmission lines that connect the Glenarm and Santa Anita receiving stations (Path 2) in the second five years of the master plan. To facilitate the replacement of these lines, PWP needs to complete the following projects within the first five years of the plan:

- Protection upgrades to thirteen subtransmission lines serving Villa, Chester, and Oak Knoll substations.
- Upgrade three of the Path 3 subtransmission lines.

7.3. <u>Evaluation of Substations and Substation Assets</u>

PWP has 12 substation facilities, consisting of nine distribution substations, one receiving station and two combined receiving and distribution substations. These facilities contain various types of equipment, which are over 30 years old on average. The industry standard for the useful life of substation equipment ranges from 30 to 50 years. PWP expects that much of the substation equipment will need to be replaced within the next 20 years. A majority of the 4 kV assets will require special attention due to age and loading conditions.

7.3.1. Power Transformers

PWP currently has 54 substation power transformers, including the three T.M. Goodrich 220/34.4 kV transformers. The average age of PWP's substation transformers is 49 years, with the oldest being nearly 65 years old and the newest being nearly eight years-old. On average, PWP's unit substations are in the last 20 percent of their expected useful life.

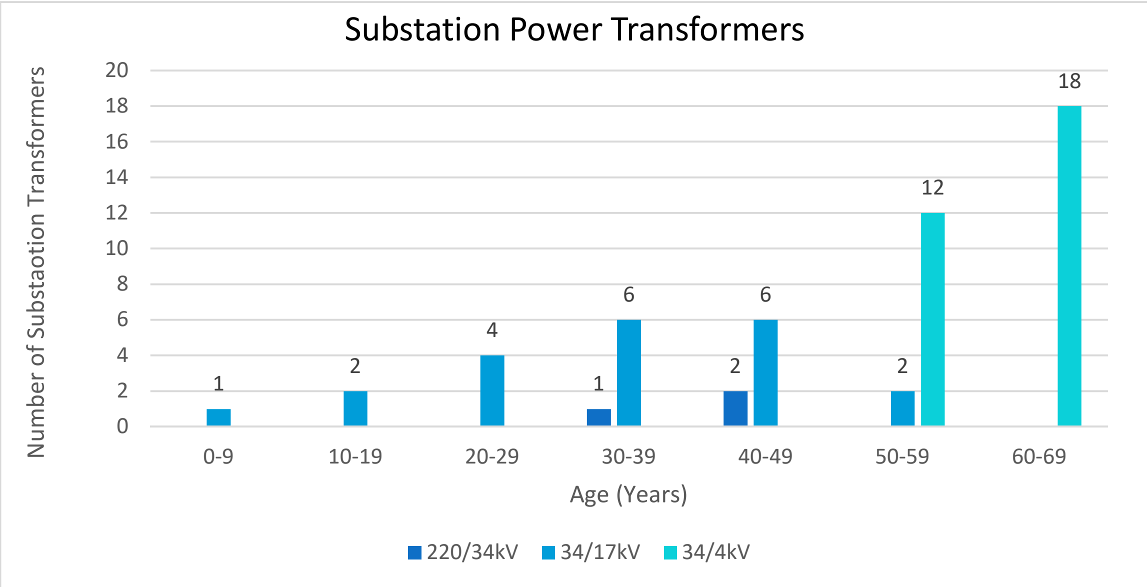


Figure 23: Substation Transformers by Age and Voltage

As seen in Figure 19, 32 out of 54 of the power transformers have surpassed their rated useful lives. By year 2031, the number of transformers over 50 years old will increase from 32 to 38, where all of the units serving the 4 kV distribution system will be greater than 60 years old. The risk of having these units fail will increase despite the prudent efforts to maintain them properly.

Figure 24: Chester 4kV Unit 1 Substation (Two Power Transformers and Connecting Switchgear)

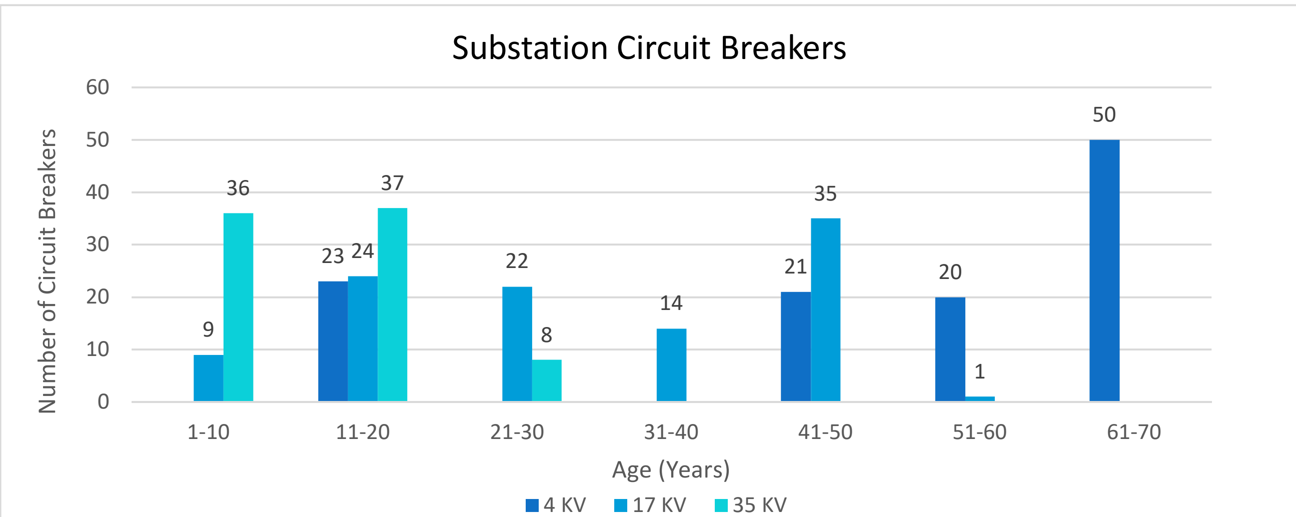
The goal established in the Master plan is to replace two substation transformers every three years on average. The transformer replacements will be done as part of replacing the entire substation units (including the switchgear and components connecting the transformers).

Finally, as PWP continues to convert 4 kV circuits to 17 kV, it will not only address a variety of different issues in the distribution system, but also allow PWP to decommission some of the older 4 kV substation transformers as well over time. PWP expects to be able to decommission approximately ten 4 kV substation transformers and their associated switchgear and circuit breakers as a result of its 4 kV to 17 kV voltage conversion program over the next 20 years, which will both reduce system risk, as well as reduce the number of assets PWP will need to maintain or replace in the future. These decommissioned units can also potentially be stored as spares if they are found to be in good enough condition.

7.3.2. Circuit Breakers

Circuit Breakers are a very important part of Pasadena's power system protection schemes and will be prioritized for maintenance or replacement to guarantee safety and reliability. Just like the simple circuit breakers in a house, these devices turn off a line if there is an overload or short circuit condition. These circuit breakers are the most important protective devices to quickly de-energize facilities when a fault occurs downstream. If a breaker does not work, tremendous damage to various distribution and transmission equipment can occur. Switchgears and their circuit breakers typically have a useful life of 40 to 50 years if properly operated and maintained.

PWP currently has 305 medium voltage circuit breakers in service, where the 4 kV and 17 kV breakers generally exist inside substation switchgears, and the 35 kV breakers are located in the receiving stations switch racks. The overall average age of circuit breakers is about 33 years. PWP will be targeting upgrades of the oldest and highest loaded



circuit breakers through its substation unit replacement program, where these breakers will be replaced along with their connecting switchgear, and substation unit transformers.

The 4 kV circuit breakers are generally the oldest in the system and will be upgraded to 25kV when substation units are upgraded. PWP is targeting the upgrade of 5 circuit breakers every three years as a part of its substation unit replacement plan. The upgraded breakers can operate at 4 kV until the corresponding distribution feeders are converted to 17 kV. Furthermore, as PWP continues its 4kV to 17kV conversion program, it will be able to remove additional 4 kV circuit breakers when their circuits have been converted to operate at 17kV.

Figure 27: Chester Substation 35kV Switches (North and South)

7.3.3. Substation Switches

PWP utilized 82 switches inside the distribution substations to connect 35kV subtransmission lines to substation transformers, or distribution feeders together downstream of the switchgears. The 4kV and 17kV switches provide maximum flexibility during maintenance activities to shift feeder loads. The 35kV switches are operationally limited where they do not support optimum protection schemes due to not having fault interrupting capability. PWP plans to strategically replace the 35kV switches with either metal-clad switchgears or fault interrupting distribution-style switches (if the fault current limits permit).

The graph below shows the breakdown of PWP's installed switches by age and insulating medium. The average age of the SF6-insulated switches is 16 years, while the average age of the oil-insulated switches is approximately 52 years. The remaining oil-insulated substation switches will be replaced within the next 10 years.

Figure 26: Circuit Breakers by Age and Voltage

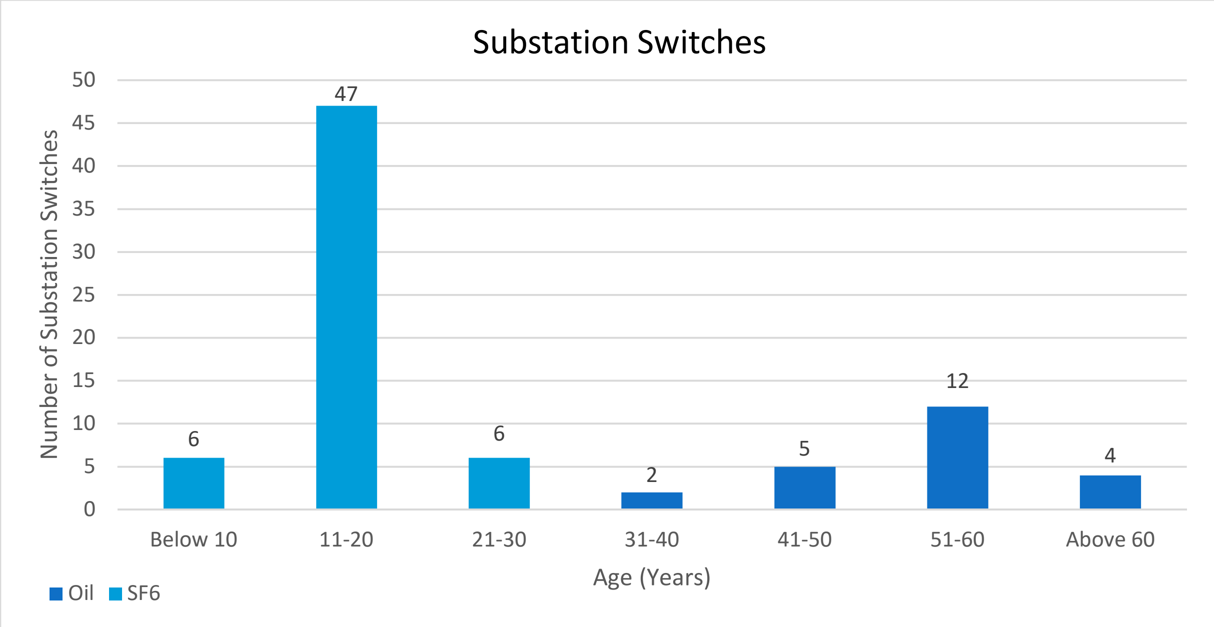


Figure 28: Substation Switches by Age and Insulation Medium

7.3.4. Substation Oil Containment

PWP has installed oil containment facilities in six distribution substations in the past 15 years to comply with the U.S. Environmental Protection Agency's ("EPA") rules regarding Spill Prevention, Control, and Countermeasure ("SPCC") Plan. PWP has also partially completed the installation of oil containment facilities in Santa Anita and Glenarm substations.

PWP will continue evaluating and installing oil-containment facilities at the remaining substations, in accordance with EPA requirements, at the rate of one substation unit every year, over the next 20 years. PWP will target the most critical/highest risk substation units first.

7.3.5. Buildings, Fencing, and Seismic Support Structures

Concrete buildings are used to house control equipment in the substation facilities. PWP has previously performed a structural evaluation of the building at Santa Anita receiving station, which describes the condition of the building, discusses deficiencies in the building, and makes recommendations for life safety improvements.

Other substation control buildings do not show any noticeable structural damages and appear to be in good condition.

PWP utilizes chain link fencing, concrete-masonry-unit fencing, and concrete walls to fence its substations. PWP should develop a design standard for the design of fencing that complies with the new California Public Utility Commission physical security requirements. PWP should use this standard when retrofitting the remaining substation structures to withstand any potential seismic event.

7.4. Evaluation of Distribution System and Distribution Assets

PWP utilizes two primary voltages in its distribution system, 4 kV and 17 kV. In general, the 4 kV distribution system is much older, has higher electrical losses, has limited capacity, and has power quality issues compared to the 17 kV system. As PWP's 4 kV equipment reaches the age where replacement is warranted, circuits will be converted to 17 kV where possible.

7.4.1. Underground Vaults/Manholes, Pull Boxes, and Conduits

PWP has 6,148 distribution vaults and manholes, with 2,023 of them being owned by customers who are responsible for their maintenance and replacement. In addition, PWP owns 1,553 pull boxes which are used to distribute power to customers. PWP utilizes approximately 785 miles of underground distribution conduit system (independent of the subtransmission conduit system) to interconnect the underground distribution system back to the substations.

A large number of vaults and manholes are deteriorating due to the corrosion of the reinforcing steel used to build the vaults. This may cause damage to equipment in vaults, be a safety hazard to workers in the vaults, and reduce the vaults' ability to support traffic weight loads.

In the past five years, PWP repaired and/or replaced 153 facilities consisting of vaults, manholes, and pull boxes. PWP conducted a risk-based assessment for distribution vaults and manholes and found that an estimated 1,735 vaults will need some level of repair or replacement. Last year, PWP refurbished 31 underground substructures, and has been on an upward trend over the last five years. PWP plans to repair or replace 50 vaults per year on average over the next the 20 years to address these vaults.

In general, the underground distribution conduit system is aging, filled, and/or undersized, similar to the subtransmission conduit system. PWP plans to continue to add new, larger conduit systems as part of its ongoing undergrounding program or system expansion to facilitate future upgrades to underground cables without lengthy interruptions, and allow for the use of larger cables.

7.4.2. Power Poles

PWP distribution system has 11,050 wooden power poles, where approximately 8,850 are primarily owned by PWP, and the remaining poles have shared ownership with other utilities like AT&T, Verizon, LADWP, and SCE. Each utility may occupy a specific space on the shared pole depending on the type of use and/or voltage class, as identified by the Joint Pole Committee ("JPC") of Southern California. Figure 26 shows the breakdown of wooden power poles in PWP electric system by age. The average age of poles in PWP's system is about 58 years, and about 60% of these poles are more than 60 years old.

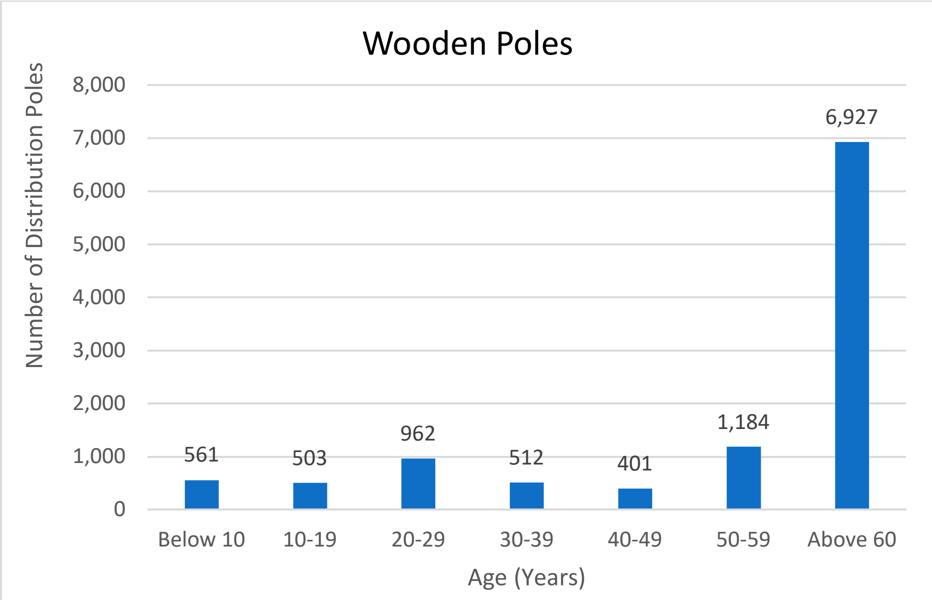


Figure 29: Wooden Poles in Distribution System by Age

The risk-based assessment for PWP distribution poles found that 249 distribution poles were identified to currently be in the highest risk category. PWP plans to address these poles as part of its comprehensive pole inspection program, where it will gather additional information to determine if immediate replacements are needed.

Many of the aging poles will last for years depending on their physical and/or loading conditions. Poles that are determined as having a high risk of failure will be replaced in coordination with switch, conductor, transformer or voltage conversion projects (to accomplish multiple objectives at once). PWP has an aggressive pole inspection program to identify poles that need replacement and prioritize their replacement based on their condition. PWP plans to replace on 120 power poles per year on average for the duration of the master plan.

7.4.3. Overhead and Underground Circuits

Table 18 shows the breakdown of overhead and underground conductors in the distribution system by voltage. About 75% of the 4kV and 17kV distribution conductors are underground, where about 35% of them do not have a record of their installation date, which is common in the industry. This makes it difficult for PWP to set an effective replacement program for these potentially aged cables. PWP assumes that these cables were installed before 1980.

Table 18: Circuit Miles of Conductor per Distribution System Voltage and Type

	Type Of Primary Conductor		Total by Voltage
Operating Voltage	**OH**	**UG**	
17kV	33.4	362.9	396.3
4kV	132.7	136.2	268.9
Totals	166.1	499.1	665.2

Table 19: Circuit Miles of Distribution System Secondary Conductor and Type

	Type Of Secondary Conductor		Total
Operating Voltage	**OH**	**UG**	
Secondary Conductor (Circuit Miles)	421.2	486.5	907.7

PWP experiences very infrequent cable failure, where most underground circuit failures occur at the splice and termination points. Based on age, PWP needs to replace at minimum one-third (about 170 miles) of its primary underground cables over the next 20 years.

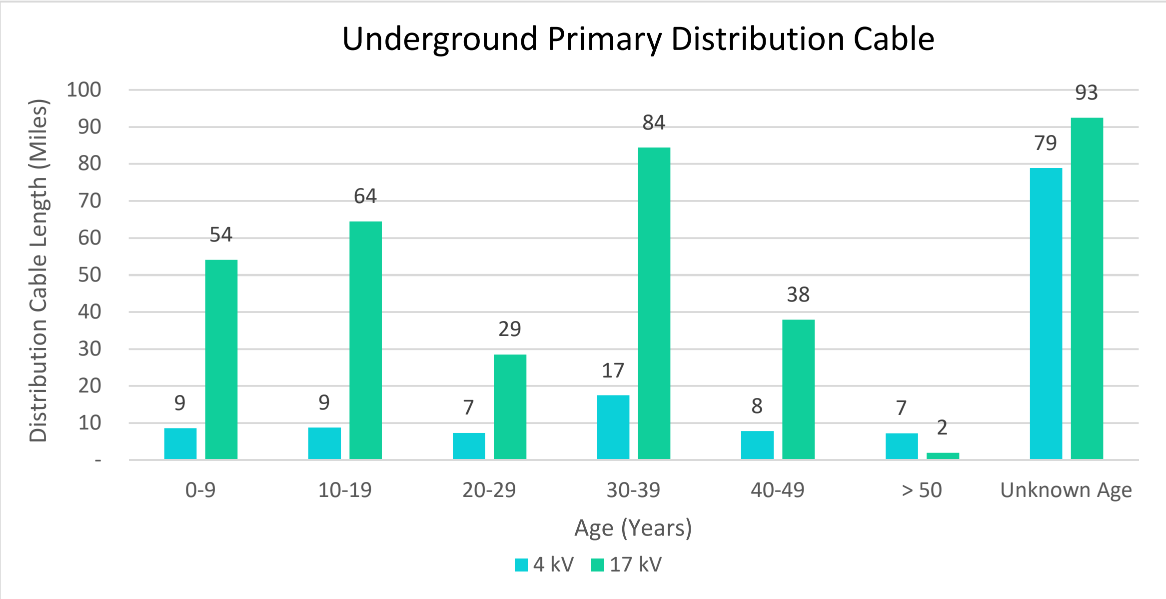


Figure 30: Length of Underground Distribution Cable by Age and Voltage

In general, PWP's underground cable should have an expected useful life of at least 45 years. PWP will continue to upgrade cable, focusing first on the Okonite Plant 7 cables where found. Okonite Plant 7 cables are a specific vintage of cable that are known to have a less than average lifespan compared to PILC and XLPE cables. The subject cables will be replaced in coordination with switch and/or vault replacements or voltage conversion program to accomplish multiple objectives at once at the least possible cost.

Replacement of overhead conductor sections should be coordinated with the Voltage Conversion program when possible to optimize synergy. New overhead conductors will be covered conductor, with bare conductor only to be used in emergency repair situations, to increase their reliability and resiliency to outages caused by contact with trees or foreign objects.

7.4.4. Overhead and Underground Transformers

PWP has 8,382 distribution transformers installed on poles, pad-mounts, and belowground in distribution vaults, as summarized per system and per operating voltages that are shown in Table 20.

Figure 32: Overhead Distribution Transformer

Figure 31: Underground Distribution Transformer

Table 20: Distribution Transformers by Type and Voltage

	Distribution System Voltage					
	17 kV		4 kV		Totals	
Equipment Type	**OH**	**UG**	**OH**	**UG**	**OH**	**UG**
Transformers	575	4,986	2,124	697	2,699	5,683

Transformer replacements will be coordinated with switch, cable, and/or voltage conversion projects where possible.

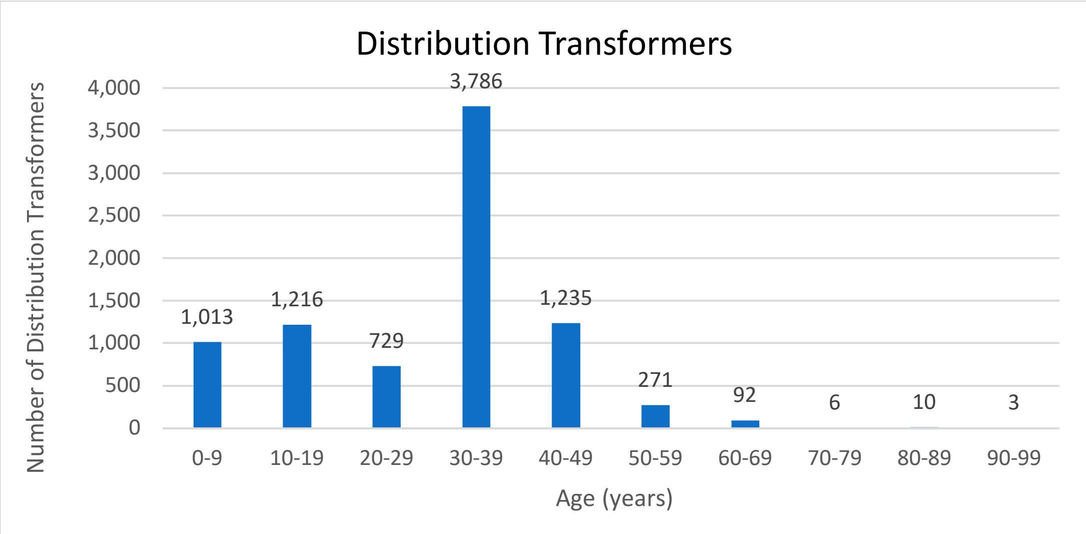


Figure 33: Distribution Transformers by Age

The risk analysis identified 111 distribution transformers to be in the highest risk category. These units will be remediated with an aggressive replacement program, coordinated with voltage conversions and underground conversion projects.

7.4.5. Overhead and Underground Switches

PWP has 546 pole-mounted switches and reclosers installed in the overhead distribution system. In the underground distribution system, PWP has 990 switches and Resettable Fault Interrupters ("RFI") installed in distribution vaults. Most of the switches are more than 40 years old, specifically the 4 kV underground oil switches. Table 21 shows a breakdown of these switches per voltage.

Table 21: Distribution System Switches by Operating Voltage

	Distribution System Voltage					
	17 kV		4kV		Totals	
Equipment Type	**OH**	**UG**	**OH**	**UG**	**OH**	**UG**
Switches	52	658	494	332	546	990

Many of the underground oil-filled switches are near the end of their useful life and are likely in need of replacement. PWP is in the process of replacing existing oil switches.

On average for the past five years, PWP has replaced 30 switches per year. Moving forward, PWP will replace at least 17 underground switches per year, preferably all with 25kV rated switches so that they can be used for future operation at 17 kV. PWP is also considering installing switches with an alternative interrupting medium to SF6 gas. As new alternatives become available, PWP will use them to comply with the expected regulations of California Air Quality Board ("CARB"), aimed to phase out SF6 insulated equipment by 2025.

7.4.6. Capacitor Banks and Regulators

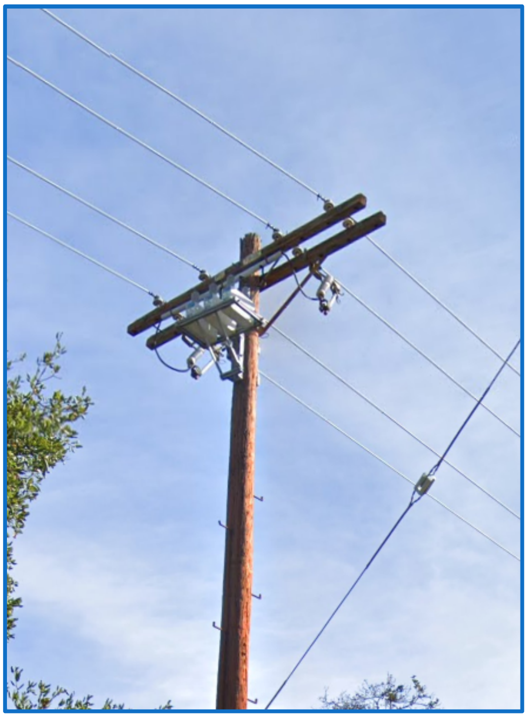


Figure 34: Overhead Distribution Capacitor Bank

Figure 35: Overhead Distribution Voltage Regulator

Generally, utilities install capacitor banks to provide voltage support, reactive power support, increase circuit capacity, and reduce system power losses. PWP has 33 fixed overhead capacitor banks installed on the 4 kV distribution system poles, and no overhead capacitor banks are installed on the 17 kV distribution system. All existing banks are always on. PWP is in the process of updating its construction standards to include advanced technologies for automated operation of the capacitor banks.

Voltage regulators are used to maintain the distribution system voltages within a pre-defined range, ensuring that electrical equipment will operate optimally. PWP utilizes a very limited number of single phase overhead voltage regulators on the 4 kV circuits where there is an excessive voltage drop during summer heatwaves. PWP may consider the use of more voltage regulators on 4 kV circuits as a cost effective alternative to regulate voltage issues can be used to reduce the need for costly upgrades in certain scenarios.

7.5. <u>Replacement Program</u>

Replacement programs are key to ensuring that utilities proactively replace equipment which is at a high risk of failure in a cost effective manner, and to minimize the amount of customer outages.

7.5.1. Existing Replacement Program

It is often difficult for PWP to perform major capital work during summer months (July-October) due to the high demand on the electric system, or in the winter months where there are construction moratoriums (November-December). This leaves a small timeframe for PWP to complete major projects.

Any solution implemented in the distribution system must improve one of the following categories (without negatively affecting the others):

1) Cost Reduction: Including energy losses per circuit, substation, transmission line, and total system.
2) Reliability: Reduce unplanned interruptions and outage durations.
3) Power Quality: Ensure that customers receive between 114V and 126V at their meter.
4) Safety: This is the most important factor, considering Employee/Contractor staff and the public near distribution system infrastructure or components. Safety is never compromised and shall be improved whenever possible.

In recent years, PWP initiated a strategy to minimize customer outages and take maximum advantage of crews when performing replacement/repair work in the distribution system. The goal is to complete as many equipment replacements as possible on every job, taking maximum advantage of an outage (if one is required) and of the crew available. With this approach, a single job could involve replacing secondary conductors, poles, transformers, switches, and/or any other component on the circuit.

Replacing the right amount of aging assets each year will help PWP avoid unplanned outages and provide safe and reliable service to customers. Table 22 shows the number of significant PWP assets per risk category and Table 23 shows the baseline for the annual recommended replacement rate for significant PWP assets.

Table 22: Number of assets per Risk Category

Risk Category	Circuit Breakers	Substation Transformers	Substation Switches	UG Switches	Poles	Distribution Transformer	Vaults	OH Conductor (Circuit Miles)	UG Cable (Circuit Miles)
Highest Risk	35	8	23	119	1,205	0	3	0	0
High Risk	32	12	0	409	2,830	178	946	103	75
Mid Risk	60	19	5	142	3,890	273	780	46	325
Low Risk	173	15	54	482	3,125	7,910	1,955	34	193
Total	**300**	**54**	**82**	**1,152**	**11,050**	**8,361**	**3,684**	**183**	**594**

In order to simplify the process of addressing replacements in the next five years, PWP staff analyzed and determined the number of assets to replace each year to maintain the current average system risk. This number is assumed to be the baseline of replacements per year to maintain the current reliability of the distribut5ion system, which is summarized per asset class in the table 23.

Table 23: Baseline for the Annual Proposed Replacement Rates

Asset	Current Annual Replacement Rate (5 Year Average)	Proposed Annual Replacement Rate
Substation Units	-	1 every 3 years
Substation switches	-	4
UG distribution switches	30	17
Distribution transformers	61	50
Power Poles	54	120
Vaults Repairs or Replacements	31	50
OH conductor (Circuit Miles)	-	4
UG cable (Circuit Miles)	9	8

7.6. Power Quality and Losses

PWP defines acceptable power quality as a clean and stable voltage on the customer premises, free of distortions, fluctuations, outages, and excessive losses. This translates to PWP needing to maintain voltage levels at customer premises between ± 5% of the nominal value. While a limited number of customers may experience power quality and voltage issues in certain areas, these issues may be caused by aging infrastructure, where the customer load has outgrown the original system design over time. Pasadena's electric system has good power quality overall compared to industry standards and comparable utilities, where only small pockets of the city experience potential issues, and those issues only arise during the hottest few days of the year. PWP is actively identifying and mitigating these issues each year to ensure all of its customers receive a high quality of service.

In the past 10 years, PWP's average losses of unbilled energy was approximately 55 GWh, or about 4.5% of the energy purchased or generated by the City. PWP's system is considered efficient compared to an average utility, which experiences losses of about 6% as reported by the Department of Energy.

7.6.1. Power Quality Assessment

Every year, PWP conducts a voltage study of the distribution system during summer peak loading conditions to assess the distribution system power quality. The identified power quality issues are typically addressed through a combination of different capital improvement projects such as voltage conversion and conductor replacement programs, as well as maintenance projects like load transfers and circuit balancing.

Voltage conversions allow PWP to completely redesign circuit sections to correct all of the loading and voltage issues, but they tend to be more costly when compared to 4 kV equipment upgrades, and thus need to be assessed for their cost effectiveness. Voltage conversion projects are ideal candidates in locations where 17 kV circuit availability is high, and where the 4 kV circuits and their elements in the same area are very old, and experience excessive loading/power quality issues. Voltage conversions will improve power quality, provide higher system capacity, and allow PWP to upgrade aging equipment with new assets.

The subtransmission system does not have significant voltage issues across the subtransmission lines or transformers under N-0 conditions for various peak or low load scenarios. PWP's subtransmission system has not experienced any major power quality issues, and does not contribute significantly to system losses.

7.6.2. System Power Loss Assessment

System power losses were analyzed by considering losses in the overhead and underground conductors (Line Losses) and transformers regardless of their voltage class. Line losses are proportional to customer load current, and are a function of the line impedances and the regulating equipment such as capacitors and transformer load tap changers. Similarly, transformer losses are proportional to customer load and transformer impedance, as well as the no-load losses from energizing the transformer.

When looking at total system power losses, the distribution system contributes more losses than the sub-transmission system. This is mainly due to the higher number of assets in the distribution system, and thus a higher volume of resistive components. The expected losses from the different equipment classes in PWP's system were estimated at a system load of 306 MW, which represent the system at a typical peak load.

Table 24: Summary of Estimated Subtransmission and Distribution Losses at Typical Peak System Load

<table>
<tr><th>Voltage Level</th><th>% of Total System Load</th><th>Equipment</th><th>Losses (MW)</th><th>% Losses (of 306 MW)</th></tr>
<tr><td rowspan="2">35 kV</td><td rowspan="2">100%</td><td>Primary Lines</td><td>2.35</td><td>0.82%</td></tr>
<tr><td>Transformers</td><td>2.09</td><td>0.68%</td></tr>
<tr><td rowspan="2">17 kV</td><td rowspan="2">80%</td><td>Primary Lines</td><td>1.45</td><td>0.47%</td></tr>
<tr><td>Transformers</td><td>1.07</td><td>0.35%</td></tr>
<tr><td rowspan="2">4 kV</td><td rowspan="2">20%</td><td>Primary Lines</td><td>2.42</td><td>0.79%</td></tr>
<tr><td>Transformers</td><td>0.34</td><td>0.11%</td></tr>
<tr><td>Secondary Voltage</td><td></td><td>Secondary Lines</td><td>3.72</td><td>1.23%</td></tr>
<tr><td></td><td></td><td>Total</td><td>13.44</td><td>4.45%</td></tr>
</table>

As can be seen from table 24, the 17 kV system serve almost 80% of the city's load, yet yield only an estimated 2.52 MW of losses, compared to the 4 kV circuits which produce an estimated 3.49 MW of losses. This is due to the lower current required to serve a given amount of load at the higher 17 kV voltage, which results in lower $I^2 * R$ losses. For this reason, among others mentioned in this plan, PWP would benefit financially from investing more resources into continuing its 4 kV to 17 kV conversion program.

Power line losses are determined by the physical characteristics and operation of the lines. Table 25 shows an example case where PWP replaces the existing Path 2 subtransmission lines between the two receiving stations, which are eight (8) 3-phase cables of 1000 kcmil AL, with 1250 kcmil CU cable. The resulting savings from a reduction in losses are estimated to be $2,347,471 over the 40 year life expectancy of the cable, if all four lines (eight cables) are upgraded. This reduction in power losses is an ancillary benefit, where the main goal is to increase the capacity of these lines.

Simply, larger cables cost more, but will result in less losses and will provide a higher capacity to improve their resiliency to system faults.

Table 25: Cost Comparison of Losses for Different Conductor Sizes for 35 kV Cross-Town Lines (over 40 years, loaded at 42%)

Conductor Size	Load Losses ($)	No-Load Losses ($)	Total Losses ($)
1000 AL	$6,198,005	$2,836,200	$9,034,206
1250 CU	$3,932,348	$2,754,387	$6,686,735

7.6.3. Alternative Solutions to Improve Power Quality and System Losses

Both utility owned and customer owned distributed energy resources such as PV solar and BESS could be used to positively impact PWP's power quality in the future. The utility could mitigate the negative impact of increased DER penetration by implementing new rules and regulations that provide more detailed connectivity requirements for new distributed generation installations.

Customer DERs can be beneficial or detrimental to the operation and economics of a power system depending on when, where, and how they are operated. For example, if too many DERs discharge onto the grid at the same time on the same line during a period of low system load, the voltage for nearby customers could rise past acceptable levels. On the other hand, these DERs could be used to offset peak load during summer heatwaves, improving nearby customers' voltage, and lowering the load on PWP's circuits. In the future, DERs may also be controlled through smart inverters, allowing for more solar penetration in the system without negatively impacting the power system.

Furthermore, other factors such as EVs could have similar effects on customers' voltage and circuit loading. Negative effects on the circuit can be mitigated by incentivizing customers to charge at low loading conditions to avoid adding that would stress the electric system.

Additionally, using the future AMI system and the new CIS for new time-or-use ("TOU") rates, PWP could potentially control the operation of DER's to optimize their effects on the distribution system. Other solutions include investing in BESS either on the PWP side of the meter or the customer side to could mitigate problems during high load scenarios, as well as during low load scenarios through the charge and discharging of the batteries onto the grid.

At a large scale, BESS applications can contribute to peak load shaving by storing energy during off-peak hours and delivering it when needed, reducing load demand during peak hours. BESS also can provide reactive power support by injecting or absorbing active and reactive power, helping voltage regulation, and reducing voltage sag caused by power system faults. They can also be used for resource adequacy ("RA"), which refers to the spare power capacity that utilities can quickly deploy when needed. RA can either be used for PWP's own peak demand needs, or sold on the CAISO market to generate revenues. Batteries can also be used for energy arbitrage, where PWP can buy energy when it is cheaper, and use it when energy is more expensive. Finally, batteries can be used to offset capital investment to increasing system capacity or improving quality through conventional means (i.e. transformer upgrades, line upgrades, etc.).

7.7. <u>Voltage Conversions</u>

Converting distribution feeder circuits to operate at higher voltages is an effective way to support higher peak load demand on a circuit. By increasing the operating voltage from 4 kV to 17 kV, the circuit would carry the same load at a current that is 75% less than when on 4 kV, which allows the same conductor size to serve four times more customer load and cover a larger service area more efficiently (less losses). Voltage conversion will also mitigate power quality issues, where the voltage drop for a given load will be reduced by 75% and load losses will also be reduced by approximately 94% when served by a 17 kV circuit.

However, converting an entire feeder from 4 kV to 17 kV entails massive equipment replacements such as substation transformer and circuit breakers, distribution transformers, switches, fuses and protective devices, and the replacement of certain poles and conductors.

Conversion costs are substantially lower when strategically transferring portions of circuits from a 4 kV circuit to a nearby 17 kV circuit. When substation construction are not needed, partial conversion of circuits are often an effective way to resolve loading and voltage problems at minimum capital cost.

However, as 4 kV substation equipment continues to age past its rated useful life, it is imperative that PWP move toward more complete circuit voltage conversions to address the substations.

Per the planning criteria and the last three annual studies of PWP's summer heatwaves, the feeders which experienced overloading were strictly 4 kV. Feeder loading and low-voltage zones are the main drivers to identify potential areas for voltage conversion. PWP has identified the Fair Oaks substation service area as the priority, where voltage conversion will achieve multiple objectives of the PDMP. These objectives include substation unit replacements, reliability and power quality improvements by replacing the aged and undersized 4 kV infrastructure with new larger 17kV infrastructure.

In the past few years, PWP has completed about 1.5 to 2 circuit miles of voltage conversions each year. PWP developed a list of the proposed voltage conversion projects with a recommended a conversion rate of about 0.74 circuit miles per year starting in 2023, which would require an estimated annual budget of about $3 million (excluding substation upgrades). After completing the required conversions of certain Fair Oaks circuits, it is recommended that the next conversion analysis be targeted at the Santa Anita and the Eastern 4 kV feeders. Subsequently, all 4 kV feeders should be re-analyzed as a part of the annual summer loading assessment for determining future conversion projects.

7.8. <u>Underground Conversions</u>

Figure 36: PWP Underground Vault Installation

Pasadena's Underground Utility Districts ("UUD") Program, was created by the underground facilities ordinance (Pasadena Municipal Code ("PMC") Chapter 13.14) in 1968. Undergrounding is the process of removing electric poles and wires, and relocating conductors to underground infrastructure and out of sight. This results in a significant visual enhancement to the City, where Pasadena has proudly achieved a Tree City USA status, recognized by The Arbor Day Foundation for more than 10 years in a row. While undergrounding can be costly, it can provide many benefits to the city such as improved aesthetics, system reliability, safety, and reduced wildfire threat risks.

7.8.1. Undergrounding Project Selection

Projects are evaluated and overhead circuits are selected by deterioration and in need of replacement, conflict with trees or structures, are in high fire risk areas, are part of planned major street construction, or are located where new power facilities are needed.

In an underground district, all existing affected overhead utilities must be identified and relocated, such as telephone and cable utilities, which requires additional coordination to avoid delays in executing the project. The program prioritizes projects located along Category I and Category II streets. Category I includes heavily used arterial and collector streets with a concentration of power lines, and streets near city landmarks and recreation areas. In general, all Category I streets should be undergrounded before Category II streets projects begin. Category II streets include residential streets and alleys.

The conversion of overhead equipment to underground includes the replacement of transformers, switches, insulators, conductors, and other equipment as well as the removal of poles and the resurfacing of the streets. These projects are completed in coordination with third party communications utilities and the streetlight and paving groups within the City of Pasadena's Public Works department.

In next five years, PWP plans to complete four underground utility districts starting in 2023. The City Council has already approved Mountain and Raymond underground utility districts, and PWP will begin design and construction of these two districts in 2023. For future projects, which include the underground utility districts for Florecita Dr and Canyon Close Rd will be proposed to the City Council for approval to mitigate the risk of wildfires. Upon approval, PWP can initiate the design and construction of these two districts starting 2026 and 2027 respectively.

7.8.2. Benefits and Challenges to Undergrounding Circuits

Ideally, when evaluating capital projects, it is preferred to assess the costs and benefits of the investment. However, in the case of undergrounding, the benefits are more subjective and difficult to quantify. The following is a list of primary benefits and disadvantages resulting from circuit undergrounding[1]:

Benefits:

- Greatly improves the aesthetics of streets by removing from sight pole lines and multiple overhead electric lines and equipment. This benefit is particularly appreciated in Pasadena where the urban forest is nurtured and enjoyed by the public, increasing customer satisfaction.
- Promotes positive economic impact by reducing outage-caused business down time, and promotes tourism by enhancing the beauty of the City, and enhancing land values.
- Increases system robustness and reliability, where underground circuits have less exposure to weather events such as windstorms, fires, falling trees or palm fronds, Mylar balloons, vehicle collisions with power poles, and animals like squirrels and birds causing power outages.
- Reduces the costs of vegetation management programs needed to provide clearance for the overhead conductors. This is especially important now more than ever considering that recent legislation increased the cost of contract vegetation management crews to PWP by three times the previous expenditures.
- Creates a safer environment for the public by eliminating the occurrence of down wires.
- Eliminates wood poles and cross-arms that are aging and require replacement or repair.
- Replace aging overhead infrastructure with new underground equipment.
- Results in circuits that are less susceptible to vandalism or terrorism.
- Reduce fire risk caused by overhead electrical facilities (new consideration for Tier 3 wildfire areas)

Challenges:

- Undergrounding construction cost is significantly higher compared to overhead construction due to the high costs associated with installing conduit and substructures, and more specialized equipment is necessary.

[1] L. Kenneth, *An Update Study on the Undergrounding of Overhead Power Lines*. Edison Electric Institute. Washington: EEI, 2013.

- Underground circuits are less likely to experience outages, but when/if they fail, the damage is more difficult to locate, time consuming to repair, and costly to repair.
- Maintenance and operation are costly, and underground systems are susceptible to flooding.

7.8.3. Underground Program Methodology

The Underground Utility District program seeks to provide a safer and more reliable system while helping to beautify the City. To start an undergrounding project, PWP evaluates its system within a specific area/zone to develop a list of potential districts. PWP reviews these potential districts with the Public Works Department to determine which district provides the most benefit to the community and eventually both departments. Then, PWP brings the recommended district(s) to the City Council for their review and approval.

This program attempts to prioritize the conversion of overhead assets in specific areas where simultaneously the overhead power system, street surface, and street lighting are at or nearing the end of their useful life. Prioritization will be given to projects located within the Tier 3 ("Extreme") wildfire threat district, with secondary consideration for areas with overhead systems installed along Category I streets, areas with overhead systems within a Tier 2 wildfire threat district, and where conversion assists with other initiatives. The presence of existing nearby underground facilities will make the total conversion much easier.

7.9. Evaluation of System Protection Practices

Electric utilities rely on protective devices to minimize the impact of electrical faults on equipment and customers' services. Electrical faults (short circuits) are serious events that feature rapid temperature rises on the equipment, significant mechanical forces, voltage sags, transient stability issues, and personnel shock hazards. Fault conditions that do not result in quick interruptions can create significant risk to both personnel and the system.

Similar to the majority of electric utilities today, PWP's system still has a substantial amount of aging equipment and protection systems installed as part of major infrastructure buildouts in the 1950s, 1960s, and 1970s. The aged protection systems are based on electro-mechanical ("EM") relays in substations that provide basic protection functionality but do not have the advanced protection and communication capabilities needed for a modern electric utility. EM relays cannot be interfaced with the PWP SCADA system, which decreases efficiency and operational capabilities for the dispatchers. In addition, most EM relays are no longer supported by manufacturers for parts or repairs, which provides issues for PWP if not replaced with modern microprocessor based relays.

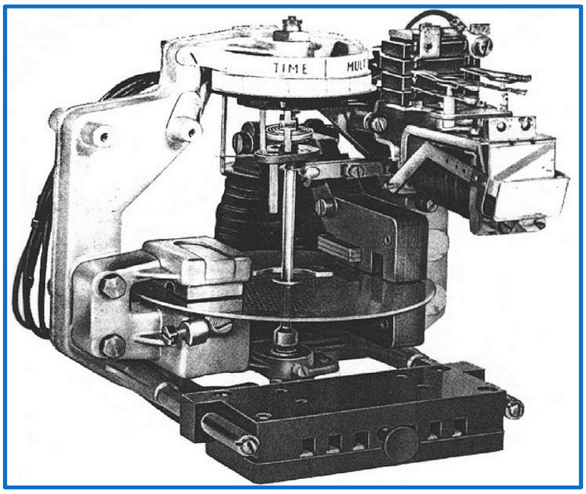


Figure 37: Vintage Electromechanical Relay

PWP is prioritizing the replacement and upgrade of major substation assets to include power transformers as part of the PDMP. In the meantime, PWP will need to continue to operate its aging substation equipment like the power transformers, which are approaching the end of their rated useful life. One strategy to maximize their useful life is to implement modern micro- processor based protection devices to rapidly detect, interrupt, and isolate fault conditions on aging equipment. These modern protection devices can drastically minimize the negative effects of fault conditions on aging equipment by interrupting faults quickly and consistently compared to the original EM protection devices.

7.9.1. Protection Systems at Receiving Stations

PWP's three receiving stations, Glenarm, Santa Anita, and TM Goodrich, are predominantly equipped with EM or first generation analog protection systems. To ensure proper protection schemes, PWP is upgrading the protection systems for:

- The three transformers at TMG and
- The switchrack busses at all three receiving stations.

Figure 38: Modern Microprocessor Based Relay

The receiving station transformers and switchrack busses are some of the most important assets in the system, and upgrading from older analog devices to newer microprocessor based relays will allow for more complex protection and enhanced remote control capabilities.

Once power is imported at TMG, it is transferred across Pasadena through the receiving stations, which are interconnected together through major cross-town 35 kV subtransmission lines. The primary protection for all of these major cross-town lines were recently upgraded to micro-processor based relays with line current differential and overcurrent protection, which was a significant achievement for PWP, given that the engineering, protection settings, and SCADA programming was completed using in-house resources. Line differential protection is based on the fact that any fault within an electrical equipment would cause the current entering it, to be different, from the current leaving it. Relays monitor the currents that flows in and out of a specific line and can quickly detect if there is a fault. Relays send commands to associated circuit breaker to isolate the line that experienced the fault protecting the cable and all associated equipment from substantial damages that might cause a loss of service for a sustained period of time, and cost the utility more than anticipated maintenance costs.

Between Santa Anita and the Glenarm Receiving Stations, there are thirteen 35 kV lines serving Villa, Chester, and Oak Knoll substations that can potentially serve as a backup path for power to the Path

2 lines. These lines are referred to as the Path 3 lines, and can be configured to support the energy transfer both from receiving station to substations, as well as between receiving stations. The energy transfer between receiving stations across the Path 3 lines will be needed to upgrade the aging infrastructure of the Path 2 lines, which is a major capital project of the PDMP. To use the Path 3 lines as a backup, PWP will need to upgrade their line protection systems. These upgrades are currently underway, and are expected to be completed within the first five years of the PDMP to allow for the upgrade of the Path 2 lines in the second five years of the PDMP.

7.9.1.1. Short Circuit Duty ("SCD") on Subtransmission System

The magnitude of the short circuit currents in the system are mainly determined by the contribution of the SCE system and the Glenarm Power Plant. A short circuit study was conducted on the present Pasadena system configuration, with full dispatch of the Glenarm generating units and three TMG transformers in service. The study showed that the estimated average values of SCD exceed the permissible design limits set by the manufacturer. Therefore, PWP operates the system with some elements out of service to stay under these limits, which causes operational inefficiencies and power import limitations.

Table 26 shows the average of the symmetrical short circuit duty for the 35 kV circuit breakers at the three receiving stations if all of the five generating units and the three TMG transformers are in service[2].

Table 26: Current Available 35 kV Fault Current – All Generators and TMG Transformers in Service

35 kV Receiving Station Name	Interrupting Rating (A)	Available Fault Current (A)	Percent of Rating
T.M. Goodrich	40,000	42,923	107%
Glenarm RSC & RSD	40,000	43,443	109%
Santa Anita 1 & 2	40,000	43,072	108%

PWP will be conducting a feasibility study to determine the best solution for reducing the fault current levels. One potential solution may be to install current limiting series reactors on the receiving station transformers at TMG and/or the transformers for the local generators at Glenarm. Any potential solution should allow PWP to operate all of its import and generation assets at the same time without violating its breaker's ratings, which will enhance system reliability, redundancy, and resiliency at peak loads. This solution could be temporary for the first half of the timespan of the PDMP, and PWP will likely need to split the system into two systems in the future to further reduce the available SCD on the 35 kV system. This is especially important when the TMG transformers are replaced with higher capacity units in the future. This process of splitting one networked system into two separate systems is common for utilities operating at 35 kV.

Splitting the system into two power zones can potentially lower the 35 kV system fault duty from the current symmetrical fault current of 40,000 Amps to under 25,000 Amps. A lower fault duty enables PWP to use less expensive substation and distribution equipment, and tend to create less damage

[2] PWP has operational procedures to keep the fault duty below the equipment ratings.

during system faults. Lower fault duties are one of the additional inherent benefits to upgrading circuits/substations from 4 kV to 17kV.

7.9.2. Protection Systems at Distribution Stations

The 4 kV substations are generally aged and include EM relays which provide less optimal protection compared to the majority of 17 kV substations which feature micro-processor based relays and higher quality protection. In general, PWP will continue to focus on upgrading the 4 kV protective devices to more modern relay solutions to extend the life of aging substation transformers and lines, and to enhance customer reliability. These upgrades will mostly be done in conjunction with substation unit replacements and 4kV substation modernization projects.

7.9.3. Protection Systems in Primary Distribution System

PWP currently uses a variety of protective devices within the overhead primary distribution system, including fuses, reclosers, and Faulted Circuit Indicators ("FCI"). Overhead systems feature a higher frequency of outages as compared to underground systems, where many of these faults are caused by tree limbs or animals causing a short circuit in the overhead lines.

PWP has also recently experienced several energized overhead line down events over the past few years, which pose a direct threat to public safety. They are known to occur during either windstorm events, or from sustained faults which cause the wires to burn up and fall from the pole. PWP has recently installed several micro-processor based relays with high impedance fault capabilities to detect when line down events occur, but this technology is still new and under engineering review.

Figure 39: Overhead Faulted Circuit Indicator (FCI)

Protective devices specific to the underground primary distribution system include Resettable Fault Interrupters ("RFI") and FCIs. Historically PWP has not used underground primary fuses in the distribution system, but is considering their use in the future as a cost effective and space efficient alternative to RFIs.

Underground outages typically do not leave obvious signs of location of fault, and field staff must troubleshoot the circuit to find the location where the fault occurred before making repairs and restoring service. FCIs make the troubleshooting process easier by providing visual confirmation of areas that experienced high fault current. RFIs are installed to minimize the impact of electric faults on our customers by interrupting faults quickly in the distribution system and sectionalizing the circuit; they are typically installed near the middle of the circuit, and at locations where the primary circuit transitions from underground to overhead to minimize the overhead portions impact on the entire circuit's reliability.

PWP will continue the use of RFIs and FCIs to maintain the high standard of reliability to its customers, as well as potentially explore primary underground fusing in the future where it may be the optimal solution for certain projects.

Figure 40: Underground Resettable Fault Interrupter (RFI)

8. OPERATIONS AND MAINTENANCE

While the PDMP mainly focuses on capital projects needed to meet the long term goals of PWP, below is a brief description and assessment of PWP's operations and maintenance practices and programs.

8.1. Project Management

PWP is in the process of procuring a Work Order Management System ("WOMS") solution to increase the efficiency and effectiveness of staff in creating, tracking, managing, and closing projects. PWP needs to implement a WOMS to better manage its projects from inception to close out.

PWP manages its assets using Cascade Asset Management System ("AMS"), which allows staff to track certain assets' attribute data, testing data, and maintenance history. The current system needs to be upgraded or replaced with a more fully featured solution, focusing on implementing the new system with a proper database structure and integrating it with WOMS and the City's financial record system (Tyler Munis). PWP will consider WOMS solutions that have AMS functionality built in it to maximize its efficiency.

The project to implement an enterprise system that combines both work order management and asset management capabilities is currently underway, and is a joint venture between Power Delivery and the Water Divisions. The project is expected to be completed within the first five years of the Master Plan.

8.2. Inspection, Testing, and Maintenance Program

The purpose of asset inspection and testing programs are to ensure the reliability of the electric system by analyzing its constituent components. Inspections acquire the information needed for compliance with the State of California Public Utilities Commission ("CPUC") General Order ("GO") requirements, as well as provide context for the future budget and CIP planning.

Currently, PWP captures testing information and compiles it into several different mediums and locations. The present testing and inspection programs meet the requirements of the CPUC GOs. However, PWP needs a comprehensive AMS to capture the information about its assets across different divisions in a consistent and actionable manner. Therefore, as discussed in the previous section, PWP is in the process of procuring an enterprise system that will feature a WOMS and an AMS.

PWP currently has staff dedicated to conducting inspections, where they capture inspection data in either the Cascade, Survey 123 databases, or on paper. The goal of the inspection programs is to identify potential problems early so they can be addressed in a timely fashion or identify assets that are nearing end of useful life so they can be prioritized for replacement. PWP uses condition based inspection programs to assess remaining life expectancy of its assets since age alone is not a deciding factor to replace assets. The inspection and maintenance programs also comply with the state mandated CPUC GO regulations.

Table 27 shows the current annual goals for PWP's inspection and testing programs.

Table 27: PWP Inspection and Testing Practices

Inspections/Testing	Annual Targeted Goal (# of Assets)	Total (# of Assets)	PWP Cycle
UG Vault Inspection (Detailed)	2,600	7,718	3-yr
Distribution Switch Oil Testing	140	424	3-yr
Substation Switch Oil Testing	8	23	3-yr
Substation/Power Plant Transformer Oil Testing	66	66	1-yr
Circuit Breaker Inspection & Maintenance (ACB)	33	130	4-yr
Circuit Breaker Inspection & Maintenance (VCB)	14	81	6-yr
Circuit Breaker Inspection & Maintenance (GCB)	82	82	Monthly
Circuit Breaker Inspection & Maintenance (OCB)	2	2	1-yr
Power Pole Inspection (Intrusive)	1,100	11,050	10-yr
Power Pole Inspection (Detailed)	2,200	11,050	5-yr
Power Pole Inspection (Patrol)	11,050	11,050	1-yr
Substation Battery Inspection/Testing	12	12	1-yr
Relay Testing (Electromechanical)	280	1,109	4-yr
Relay Testing (Solid State/Micro)	50	290	6-yr
Substation Transformer Load Tap Changer (LTC) Maintenance	9	54	6-yr

8.2.1. Underground and Overhead Inspection Program

Today, inspection data for both overhead and underground distribution assets is captured by paper and manually transcribed later into the electronic Cascade database. The staff primarily use their experience and a visual inspection of the equipment to recommend individual assets for replacement. Substructure inspections usually identify issues that are later used to generate work orders to repair, reinforce, or replace underground structures. Pole inspections can lead to pole replacements if the pole is found to be in poor condition. If a pole replacement is determined to be necessary, PWP will assess if adjacent equipment in the area could also benefit from being upgraded/replaced in the area to maximize the return on investment of the pole replacement.

8.2.2. Substation Inspection and Maintenance Program

Substation equipment is inspected and tested per the table 27 above, and reports of the testing and maintenance are stored in both Cascade and in the North American Electric Reliability Corporation ("NERC") Compliance SharePoint site for reporting purposes.

PWP utilizes a consultant to perform gas spectroscopy and oil testing on the substation transformers, currently performed twice a year. The testing is performed periodically, and requires manual sampling. Currently, PWP has an online Dissolved Gas Analysis ("DGA") system installed on Fair Oaks Transformer Units 3A and 3B, and on TMG Transformer Unit 3, and is planning on installing more of these devices in the future. These units will allow for more complex analysis of the health of oil filled assets, and can be used to prevent certain failures that can be predicted from continuous monitoring of the assets. Staff also conduct infrared inspections on substation equipment to check for hot spots on equipment which may signal equipment stress.

8.2.3. Power Line Clearance Program

Power line clearance is a program to trim/clear vegetation away from high voltage power lines to maintain proper distances between energized conductors and vegetation at all times. This program only applies to vegetation that is in close proximity to power lines, and is performed on a 3-year cycle. Currently, PWP meets the industry standard for vegetation management practices. State prevailing wage changes in the tree trimming sector have tripled the cost of outside power line tree trimming contractors. Due to this increase, PWP may consider having internal staff to plan and execute an in-house tree trimming program if it is expected to be cost effective to do this function internally.

9. GRID TECHNOLOGY AND MODERNIZATION

The modernization of utility infrastructure includes the upgrading of systems such as metering, protection, control, and communication. Upgrading existing equipment to modern devices and systems offers automation capabilities across the distribution and subtransmission systems. The major initiatives for utility modernization and automation include upgrading the metering system to an AMI system, continually upgrading the existing SCADA system to support distribution substation automation. Implementing more system automation improves dispatchers' ability to monitor and control components, and enhances system reliability, and workforce safety and efficiency.

9.1. Metering Infrastructure

PWP provides electric service to approximately 67,500 customers, consisting of around 58,500 residential and 9,000 commercial customers. Commercial meters are typically read on a monthly cycle and residential meters are typically read on a bi-monthly cycle. Presently, PWP's meter reading processes utilize Automatic Meter Reading technologies.

9.1.1. Existing Automated Meter Reading ("AMR") System

AMR is a one-way communication technology that allows meter reading from the street; the meters transmit an Encoder Receiver Transmitter ("ERT") radio signal while the meter readers drive by with handheld receivers. Since the creation of the previous PDMP in 2005, PWP has upgraded nearly all of its residential and small commercial electric meters from traditional electromechanical meters to the AMR system.

9.1.2. Future AMI System

AMI is the integration of smart meters, a communications network, and a meter data management system, which allows for wireless two-way communication between PWP and its customers' meters.

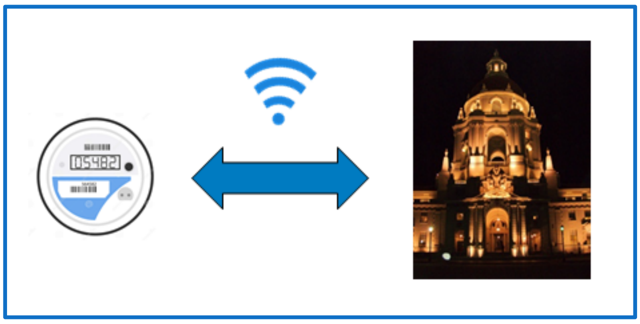


Figure 41: Future AMI System

Much like the evolution of smartphones, which has developed a myriad of new applications aside from voice communications, a smart grid deployed with AMI will enable new capabilities over time. As a starting point, AMI will offer functionalities such as remote disconnect/reconnect of service, voltage monitoring, automated real-time outage notification, and support for dynamic rates. This is in addition to customer benefits such as on-line usage monitoring and increased rate options with the improved metering capabilities.

Interval energy data is a fine-grained record of energy consumption, with readings made at regular intervals throughout the day, every day. AMI will leverage interval energy data at the customer meters to allow PWP to provide more detailed rate structures such as Time of Use ("TOU") rates to its customers. This provides comprehensive rate structures and electric usage data to customers, giving them more control on how they use their electricity and manage their bill.

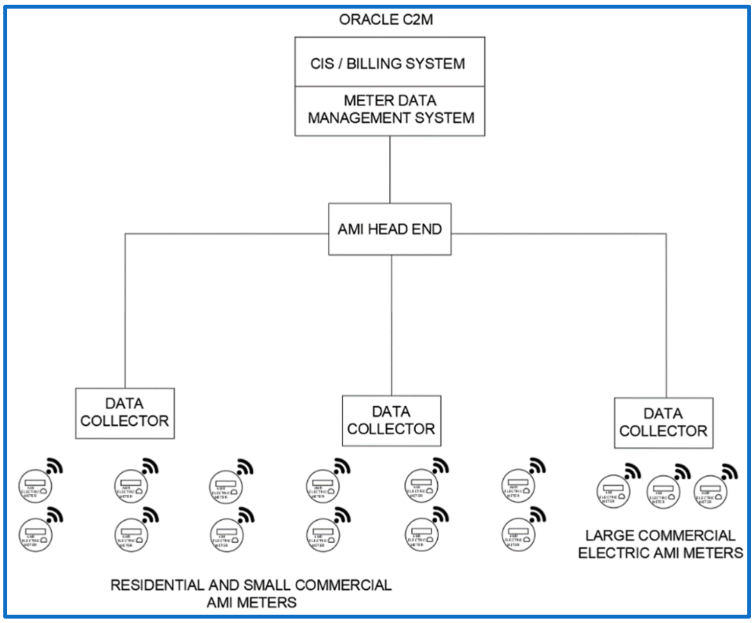


Figure 42: Proposed AMI System Topology

With the evolution of the electric utility industry and the introduction of many new technologies such as EV and renewable energy (such as solar and energy storage), TOU rates can empower customers to lower their electric bills and take advantage of cleaner and cheaper renewable energy by shifting their load profiles to low demand periods. AMI will also provide benefits to the utility and to the City of Pasadena in the form of an overall reduction in labor costs and CO2 emissions associated with drive by meter reading and operation, by providing more comprehensive and reliable outage management capabilities and notifications to its customers.

PWP plans to implement AMI to provide additional benefits to its customers which the current AMR system is incapable of providing. The AMI system selected must support and provide the following critical business functions at scale: near real time data acquisition for OMS and billing structures, CIS integration, OMS integration, and real time voltage data. PWP is currently in the process of upgrading its CIS system, and is expected to go live in the third quarter of Fiscal Year 2022, with a stabilization date in the first quarter of fiscal Year 2023.

The AMI project will involve the replacement of existing AMR meters with AMI meters, and the installation of data collectors throughout the city. All data will be routed to the new CIS system for billing and the development of comprehensive rate structures for PWP customers to manage how they use energy.

The conversion to AMI also provides the opportunity to inspect each meter installation, identify and report code violations, and detect power theft. Additionally, PWP will be conducting a cost of service study that may lead to developing new rate structures to offer a greater range of rate flexibility to its customers. These new rate structures and incentives cannot be accurately offered without the implementation of AMI and the interval data it provides.

After the full AMI deployment, PWP should consider integrating future smart grid technologies and programs. This can include a customer engagement portal for customers to obtain their interval metering data, estimate bill usage, and receive automatic outage notifications. Furthermore, PWP should explore designing time of use rates and demand response programs to gain the full benefit of an AMI system.

9.2. SCADA and OMS

PWP uses a variety of software tools to operate and maintain its electric system. On the operations side, power dispatchers continuously monitor the electric system, using SCADA and OMS, 24 hours a day, 365 days a year, to ensure that the system is operating safely and reliably. SCADA was originally implemented in the early 2000s, and has been upgraded multiple times since. The SCADA system recently received a full system upgrade in 2021.

SCADA is an enterprise system of hardware and software used to monitor and control the real-time status of PWP electric system. SCADA gives remote visibility and control of major assets (such as substation breakers) to power dispatchers, which help to track the status of the electric system.

Overall, the SCADA system has met the operational needs of PWP and allows for extensive custom user configurability. Since the original installation, the SCADA system has achieved a high level of reliability with no significant operational failures.

The OMS is used to track outages and manage the restoration of power to its customers. The original installation of PWP's OMS was completed in 2014 as a direct response to the 2011 City of Pasadena Windstorm Natural Disaster. As part of the OMS installation, PWP additionally implemented a hosted Interactive Voice Response ("IVR") enterprise software solution by Milsoft to provide overflow automated customer call handling and response.

These systems must consistently be patched and routinely upgraded every 6 years for security reasons, and to integrate new software improvements. PWP plans to upgrade its OMS and SCADA systems in FY28 with one solution that integrates the OMS, SCADA, and DMS capabilities into one comprehensive system.

A DMS is an automated system that uses data SCADA with other databases such GIS to automate the operation of the distribution system, such as optimal automated switching and circuit reconfiguration, which help to minimize outage scope and duration. DMS may be utilized to automate equipment on the distribution system such as LTCs, regulators, capacitor banks, and switches to optimize circuits and system power quality, improving customers' quality of service.

9.3. System Automation

The PWP electric system has significant amounts of automation in operation today. Automation at PWP generally refers to projects and equipment that gives dispatchers remote visibility and/or control of system components, or that automate the operations of field devices to improve power grid efficiency and reliability.

Automation projects have been integrated throughout PWP's receiving stations, substations, distribution system, and enterprise software. The majority of the automation projects have been completed to support the Primary Dispatch Center, used to centrally monitor and control PWP's electric system. These projects include the installation and continual upgrade of SCADA, the citywide fiber network, and the installation of microprocessor-based relays and communication devices at the substations to provide the dispatchers remote control and/or monitoring of substation assets such as circuit breakers, transformers, and capacitors.

9.3.1. Receiving Station Automation Assessment

Receiving stations are critical to the operation of Pasadena's power system and needs to be the priority for automation projects moving forward to maintain reliability and to ensure the safety of employees.

Table 28 shows a summary of the 35 kV circuit breakers at the receiving stations. Over half of the 35 kV breakers have SCADA visibility, but many still lack both visibility and remote control. These two functions are vital to the dispatchers' ability to operate the system effectively, efficiently, and safely. PWP is currently implementing an aggressive automation plan at the Santa Anita Receiving Station to upgrade all breakers and protection schemes. This plan should be completed by the end of fiscal year 2025.

Table 28: Receiving Station 220 kV and 35 kV Breaker Automation Capabilities

Receiving Station	SCADA Visibility	SCADA Control	Total Breakers
Glenarm	26	1	37
Santa Anita	13	6	26
TMG	19	14	23

9.3.2. Substation Automation Assessment

Major efforts have been made in the last decade to upgrade communication, metering, and protection equipment at substations from older analog technologies to digital, micro-processor based technologies. Equipment such as meters, relays, and alarms have been the primary focus for automation upgrades at the substations. PWP has also focused on installing new technologies such as on-line DGA units, which allow dispatchers to actively monitor transformer banks for their status through SCADA, and potentially predict future failures based on real-time analysis by the installed equipment.

9.3.3. Distribution Automation Assessment

Distribution Automation has been implemented on the PWP system by interfacing devices with SCADA either using fiber optic or cellular based communication. Multiple SCADA enabled underground and overhead distribution automation devices have been installed in the last five years, which provide remote control capabilities and real-time updates to Dispatch personnel.

One challenge related to DA devices is the resource intensive nature required to maintain the equipment once it's been installed, requiring on-going hardware, software, and firmware updates that are engineering resource intensive.

Major DA devices utilized by PWP include overhead and underground FCIs, reclosers, RFIs, and Automatic Transfer Switches (“ATS”). Some of these devices have the capability of communicating with SCADA for status, telemetry, and control. However, many of these devices that use cellular based communication are currently experiencing communication/firmware issues that is causing them to provide minimal usability for PWP. For this reason, PWP is switching from the less reliable cellular solutions and moving its DA devices to its own fiber system.

9.4. Communication System

Communication technology plays an important role in power system operation and management. The need for more efficient power system operation, improved reliability, and faster response to events are driving utilities to implement modern communication technologies into their major capital improvement programs.

PWP began installing modern communication technologies around the year 2000. At that time, PWP completed construction of its twenty-five (25) miles of fiber optic ring. The majority of the fiber optic cable was managed by the City, and subsequently leased to a tele-communications carriers to support local competition and to fund network deployment. The original route of fiber optic ring was completely over-built between 2015 and 2019, as well as several fiber optic expansion projects outside the original ring route, in an effort to expand the reach of its fiber optic communication network.

PWP currently has access to significant fiber optic resources, including fiber optic access in all of its substations. Specific sections of PWP’s fiber optic resources have been identified for ring, distribution automation (“DA”), tele-protection, and information technology (“IT”) usages. PWP has adequate fiber optic infrastructure for current and future needs for several years.

The fiber multiplexers are mission critical pieces of equipment for system reliability and operation. There are fiber multiplexers at each of the 11 substations/receiving stations and an additional unit at Dispatch. They translate data from the substation relays and data concentrators to the fiber network, and efficiently route traffic on the fiber network back to Dispatch. They also provide a fail-over function to the fiber network, where a single break in the fiber ring will not create any impact to SCADA’s functionality. The existing fiber multiplexers are considered obsolete because of the lack of available vendor support and ability to obtain spare parts, and are in need of capital upgrade within the next three years.

Many devices within PWP stations today have no external communication capabilities, and have to be checked in-person by PWP personnel on a frequent basis. These devices include tap changer controllers, transformer temperature controllers, protection relays, and metering. These devices will be targeted in the PDMP to have communication capabilities installed.

AMI will utilize the extensive fiber optic infrastructure throughout all portions of City. PWP will work with the selected AMI vendor to identify all of the fiber optic infrastructure expansions needed to support needed wireless collector locations.

10. FUTURE SYSTEM UPGRADES

10.1. Summary of Proposed Capital Budgets

Given all of the projects and programs mentioned in the previous sections, such as asset replacements, cable upgrades, substation upgrades, and new grid technologies like AMI and DMS/DA, PWP developed a comprehensive project list and summary of the estimated costs. The 2023-2042 CIP Master Plan has been crafted to be comprehensive and effective, including consideration of the financial impacts and revenue requirements. Table 29 shows a high level summary of the proposed annual budgets as listed in the executive summary. The average annual budget for each of the first five years of the PDMP reflect a higher budget than average historical levels due to the prioritization of projects within multiple goal categories of the CIP Master Plan. The funding sources for the proposed projects in the next five years will be re-evaluated every year to allow PWP the opportunity to adjust and/or seek appropriate methods of financing or funding. Furthermore, the human resources needed to carry out and complete all of these projects are discussed in Chapter 11.

Table 29: Summary of Proposed PDMP Capital Budgets for First Five Fiscal Years ("FY") and Last 15 Fiscal Years (in Millions of USD)

Goal	Total for First 5 Years (FY 23-27)	Total for Last 15 Years (FY 28-42)	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027
Reliability and Safety	$102.8	$222.6	$12.9	$21.9	$22.5	$20.7	$24.8
Resiliency	$32.5	$159.9	$3.4	$10.2	$6.4	$2.9	$9.5
Grid Edge	$50.6	$6.3	$2.3	$4.1	$18.3	$24.0	$2.0
Grid Modernization	$20.1	$47.0	$5.2	$4.8	$5.5	$2.7	$1.9
Power Quality	$17.8	$53.3	$3.6	$3.6	$3.6	$3.6	$3.6
PDMP Subtotal	**$223.8**	**$489.0**	**$27.4**	**$44.6**	**$56.3**	**$53.8**	**$41.7**
Customer Projects	$26.8	$81.8	$5.2	$5.3	$5.4	$5.5	$5.6
Grand Total	**$250.5**	**$570.8**	**$32.5**	**$49.8**	**$61.6**	**$59.2**	**$47.3**

In addition to this high level summary in table 29, there are also detailed tables below which list the individual projects of each PDMP goal category over the next 20 years, as well as their schedule and budget estimates. This is a high-level starting point for long term planning, and will be revised each year to account for any changes in PWP's needs or its capability to complete each project.

Table 30: Summary of Reliability and Safety Capital Projects (in Millions of USD)

Goal	Project Subgroup	FY 23	FY 24	FY 25	FY 26	FY 27	FY 28	FY 29	FY 30	FY 31	FY 32	FY 33	FY 34	FY 35	FY 36	FY 37	FY 38	FY 39	FY 40	FY 41	FY 42
Reliability and Safety	35 kV Capacitor Upgrades		0.5				0.5				0.5				0.5			0.5			
	4kV Substation Modernization	0.7	0.7	0.7	0.7	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	BK-4 Protection and Control Upgrade			0.2																	
	BK-5 Protection and Control Upgrade			0.2																	
	Brookside Substation Upgrade (Unit 1 Replacement)																			2.8	2.8
	Canyon Close Underground Conversion				0.1	5.4															
	CAPS 10-12 Protection Upgrade	0.1																			
	CAPS 4-6 Protection Upgrade	0.2																			
	Chester Substation Upgrade (Unit 1 Replacement)													2.8	2.8	2.8					
	Conductor Replacement Program	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
	Customer Facility Replacements	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
	Del Mar Substation Switch Upgrade				0.2	4.7	5.1														
	Deteriorated Pole Replacement Program	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
	Distribution Switch Replacements	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
	Distribution Transformer Replacements	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
	Eastern Substation Upgrade (Unit 2 Replacement)																2.8	2.8	2.8		
	Electrical Vault Replacement and Reinforcement	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	Emergency T&D System Replacements	1.4	1.4	1.3	1.3	1.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Fair Oaks 35 kV Switch with Interrupter Upgrade																				
	Fair Oaks Substation Upgrade	0.2	5.0	5.0	0.0																
	Fire Threat Mitigation Tier 2 Areas	0.9	1.2	0.3	0.3	0.3	0.6	0.6	0.6	0.6	0.6										
	Florecita Underground Conversion		0.1	0.0	2.7																
	Glenarm Substation Upgrade (Unit Replacement)										2.8	2.8	2.8								
	Mountain St. Underground Utility District	0.2	3.8	0.3	0.9																
	N Tie Protection and Control Upgrade / Santa Anita RS		0.2																		
	Power Quality Meter Upgrades	0.1																			
	Power System Equipment	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	Raymond Ave. Underground Utility District	0.1	0.6	6.0	4.5	3.3															
	Restraint Systems and Lid Enhancement for Vaults	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	S Tie Protection and Control Upgrade / Santa Anita RS		0.2																		
	Santa Anita Substation Upgrade (Unit Replacement)							2.8	2.8	2.8											
	Security Enhancements at Glenarm and Dispatch	0.2																			
	Security, Access Control, and Lighting	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Seismic Retrofit of Historic Building (Santa Anita)													2.0							
	Seismic Upgrade of Power Facilities	0.5	0.3	0.2	0.4	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	Series reactor study and construction (EPC)	0.1	0.1	0.8	1.4	1.4															
	Substation Oil Containment	1.2	0.8	0.4	1.2	0.6	0.8	0.8													
	Utility Undergrounding - Outside Established Districts	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Utility Undergrounding for New District						2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	Total =	12.9	21.9	22.5	20.7	24.8	18.4	15.5	14.7	14.7	15.2	14.1	14.1	16.1	14.6	14.1	14.1	14.6	14.1	14.1	14.1

Table 31: Summary of Resiliency (Cables) Capital Projects (in Millions of USD)

Goal	Project Subgroup	FY 23	FY 24	FY 25	FY 26	FY 27	FY 28	FY 29	FY 30	FY 31	FY 32	FY 33	FY 34	FY 35	FY 36	FY 37	FY 38	FY 39	FY 40	FY 41	FY 42
Resiliency (Cables)	34-10 Protection Upgrade								4.2	4.2											
	34-10 Protection Upgrade	0.1																			
	34-11 Protection Upgrade	0.1																			
	34-12 Cable Upgrade										4.0										
	34-13 Cable Upgrade														1.5						
	34-14 Cable Upgrade															1.5					
	34-15 Protection Upgrade	0.1																			
	34-16 Protection Upgrade	0.1																			
	34-19 Protection Upgrade			0.2																	
	34-20 Cable Upgrade		2.7	0.0																	
	34-20 Protection Upgrade			0.2																	
	34-23 Cable Upgrade	0.0															3.8				
	34-23 Protection Upgrade			0.2																	
	34-24 Protection Upgrade		0.1																		
	34-25 Protection Upgrade		0.1																		
	34-27 Cable Upgrade																				3.3
	34-27 Protection Upgrade		0.2																		
	34-28 Cable Upgrade															3.3					
	34-28 Protection Upgrade		0.2																		
	34-29 Protection Upgrade			0.2																	
	34-3 Cable Upgrade								2.0												
	34-3 Protection Upgrade				0.4																
	34-30 Cable Upgrade			2.7	0.0																
	34-31 Cable Upgrade																	2.2			
	34-31 Protection Upgrade					0.4															
	34-32 Cable Upgrade																		2.2		
	34-32 Protection Upgrade					0.4															
	34-4 Cable Upgrade	2.5	0.0																		
	34-4 Protection Upgrade					0.4															
	34-7 Cable Upgrade																			1.6	
	34-7 Protection Upgrade				0.4																
	34-8 Cable Upgrade																			1.6	
	34-8 Protection Upgrade				0.4																
	Add Path 1 Protective Equipment										1.0	1.0									
	Add Path 1 Cable and Conduit (North)											3.9	3.9								
	Add Path 1 Cable and Conduit (South)												3.9	3.9							
	Path 2 Cable Upgrade					4.0	8.6	8.6	8.6	4.6											
	Path 2 Substructure Upgrade/Repair					2.5	5.0	4.5	6.6	2.5											
	Total =	2.9	3.4	3.6	1.2	7.7	13.6	13.1	21.4	11.3	5.0	4.9	7.8	3.9	1.5	4.8	3.8	2.2	2.2	3.2	3.3

Table 32: Summary of Resiliency (Station Equipment) Capital Projects (in Millions of USD)

Goal	Project Subgroup	FY 23	FY 24	FY 25	FY 26	FY 27	FY 28	FY 29	FY 30	FY 31	FY 32	FY 33	FY 34	FY 35	FY 36	FY 37	FY 38	FY 39	FY 40	FY 41	FY 42
Resiliency (Equipment)	Chester 35kV Switchgear	0.2	2.7	2.7	0.0																
	Del Mar 35 kV Switch Upgrade																				
	Extend Santa Anita 34kV Rack									1.3	1.3										
	Feasibility Study Split System						0.5														
	TMG 220kV Breakers							1.3	1.3	1.3											
	Mobile Transformer	0.2	4.0	0.1										0.5							
	Oak Knoll 35 kV Switch Upgrade				0.8	0.8															
	Oak Knoll 35kV Switchgear								2.7	2.7											
	Phase Shifting Transformer				0.1	0.2	4.5	4.5									0.9				
	RFP for TMG Bank Upgrades						0.6	0.7	1.4	1.4	1.4										
	TMG 34kV Rack Work for Split System								2.0	3.0											
	TMG Bank Upgrade (Bank 1)							6.0													
	TMG Bank Upgrade (Bank 2)								6.0												
	TMG Bank Upgrade (Bank 3)									6.0											
	Transmission System Enhancement	0.1	0.1	0.1	0.1	0.1	1.3														
	Villa 34kV Switchgear										2.7	2.7									
	Villa 35 kV Switch Upgrade				0.8	0.8															
	Total =	0.5	6.8	2.9	1.7	1.8	6.9	12.5	13.4	15.6	5.4	2.7		0.5			0.9				

Table 33: Summary of Grid Edge, Grid Modernization, and Power Quality Capital Projects (in Millions of USD)

Goal	Project Subgroup	FY 23	FY 24	FY 25	FY 26	FY 27	FY 28	FY 29	FY 30	FY 31	FY 32	FY 33	FY 34	FY 35	FY 36	FY 37	FY 38	FY 39	FY 40	FY 41	FY 42
Grid Edge	AMI Implementation	0.4	2.1	16.3	22.0																
Grid Edge	Electric Vehicle Charging Infrastructure	2.0	2.0	2.0	2.0	2.0	0.8	0.8	0.8	0.8	0.8	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	Total =	2.4	4.1	18.3	24.0	2.0	0.8	0.8	0.8	0.8	0.8	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Grid Modernization	Backup Dispatch Center										0.3										0.3
Grid Modernization	CAISO Metering Upgrade at TMG and Power Plant	0.5	0.6	0.6												0.3					
Grid Modernization	Distribution System Automation	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Grid Modernization	Distribution System GIS Enhancements	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Grid Modernization	Engineering Analysis Tools Upgrade			0.1	0.1																
Grid Modernization	Fiber Optic Cable Expansions/Overbuilds	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Grid Modernization	Glenarm Receiving Station Upgrades (New Control House)	0.8	0.1	0.2	1.3	1.3	2.4	2.4										0.5			
Grid Modernization	Glenarm RSC/D 35kV PTs, Capacitor interrupters, Battery Chargers, and GT Differential Protection Upgrades	0.3	0.3	0.3																	
Grid Modernization	OMS, DMS, and SCADA Upgrade						3.0										3.2				
Grid Modernization	Primary Dispatch Facility Remodel	0.5	1.0	1.0									0.5								
Grid Modernization	RSC Linear Coupler/ Circuit Breaker Upgrade Project							2.7													
Grid Modernization	RSD Linear Coupler / Circuit Breaker Upgrade Project						2.8														
Grid Modernization	Santa Anita 17kV Substation Upgrades	0.2	0.3	0.3													0.3				
Grid Modernization	Santa Anita 35kV Bus Differential Upgrades						2.2	2.1													
Grid Modernization	Santa Anita 35kV Receiving Station Upgrades	1.2														0.2	0.5				
Grid Modernization	SCADA Communication Equipment (Every 10 Years)	0.6	0.8	1.5	0.8								1.7	1.7	1.7						
Grid Modernization	TMG Control House							2.4	2.4	2.4											
Grid Modernization	TMG Linear Coupler / Circuit Breaker Upgrade Project							2.7													
Grid Modernization	Work Order Management System and Asset Management System	0.5	1.2	1.0							0.5						0.5				
	Total =	5.2	4.8	5.5	2.7	1.9	10.9	12.8	2.9	2.9	1.2	0.5	2.7	2.2	2.2	1.0	4.9	1.0	0.5	0.5	0.8
Power Quality	4kV to 17kV Distribution System Conversions	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Power Quality	Distribution System Expansion	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Power Quality	Distribution Volt/Var Enhancements	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	Total =	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6

11. HUMAN RESOURCES

In the coming years, the Power Delivery Division will have to deploy the capital improvement projects listed in the previous section to maintain system reliability under normal or contingency conditions. To complete these projects, PWP needs to secure adequate staffing needed for each project.

This report focuses on identifying the minimum required internal staffing needs, and the estimated additional contracted resources needed, to successfully implement the recommendations of the PDMP. PWP will revisit the assumptions, budget estimates, and constraints annually to ensure they are still valid, accurate and applicable.

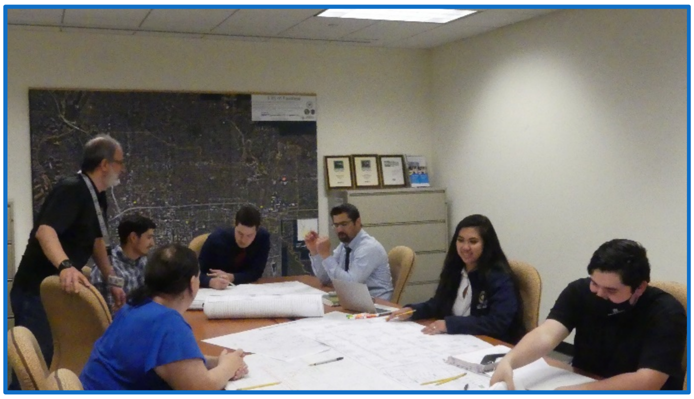


Figure 43; PWP Engineering Staff

11.1. Objective

The objective of this section is to identify the minimum number of Full-Time-Employees (“FTEs”) required to complete the recommended projects in the Master Plan within the allotted time. PWP will determine the number of additional FTEs required per year for the next 20 years. To maximize their efforts, PWP may choose to supplement the internal FTEs with contractors for specific projects.

The Power Delivery Division is organized by functional sections that are responsible of operating and maintaining the power distribution system. The four Power Delivery sections are: Engineering, Transmission and Distribution (“T&D”), Electric Testing and Construction (“ET&C”), and Power Dispatch. Currently, PWP’s Power Delivery Division has 158 FTEs, whereas approximately 18% of the FTEs are vacant. The breakdown of the current staff positions available are shown in table 34.

Table 34: Number of Power Delivery Full-Time Employees

Power Delivery FTEs*, April 2022			
Sections	**Filled**	**Vacant**	**Total**
Engineering	34	6	40
Power Distribution (T&D)	50	12	62

Electric Testing and Construction (ET&C)	33	4	37
Power Dispatch	15	2	17

* Number of employees/vacant positions continuously varies. The total number of employees is fixed.

11.2. Review of Current Staffing Allocations

PWP analyzed the historical financial data for fiscal years FY 2018-2020 to determine the average staff time currently spent on Capital Work and Operation & Maintenance ("O&M") work on average. This is an important metric because it will determine how many employees are required in the future to complete the capital budgets listed in the PDMP. The four groups' current expense ratios between Capital and O&M work are listed in table 35.

Figure 44: PWP Field Staff in action

Table 35: Current Power Delivery Capital Expenses vs. O&M Expenses

Department	Capital Expense	O&M Expense
Engineering	42%	58%
Power Distribution (T&D)	50%	50%
Electric Testing and Construction (ET&C)	17%	83%
Power Dispatch	-	~ 100%

In Table 35, the Power Dispatch group is nearly 100% working in an O&M capacity, and therefore it has no impact on the Capital Budget.

11.3. Resource Requirements for Capital Work

The recommended CIPs during the term of the PDMP will generate a resource requirement for the Power Delivery division. Labor hours have been identified for engineering work, T&D field construction, and ET&C field construction. Field operations include crew work, as well as construction management and supervision for the installation and commissioning of new equipment and infrastructure. The required resources have been identified taking into account the number of CIPs and individual projects proposed in the PDMP, using real historical data to drive assumptions for employee cost, efficiency, and capital work availability for each working group.

Given that some of the projects in the PDMP have a shorter timeframe, there will likely be less long-term value in acquiring additional internal resources for their development. Thus, PWP determined that the core work, which needs to be performed every year by internal staff, whereas external contracted resources can be used to complete the additional intermittent work that has been identified in the 20 years of the PDMP term.

PDMP goals are achievable by properly managing the vacancy rate (to keep it as low as possible) and hiring outside contractors to fill the gaps.

Some examples of large capital improvements projects that are ideal for the use of outside contracted labor – with oversight and management of PWP's internal staff – include the TMG transformer replacements, phase shifting transformer installation, and AMI implementation.

Figure 38 shows the expected number of internal and contracted employees needed for the first 10 years of the PDMP.

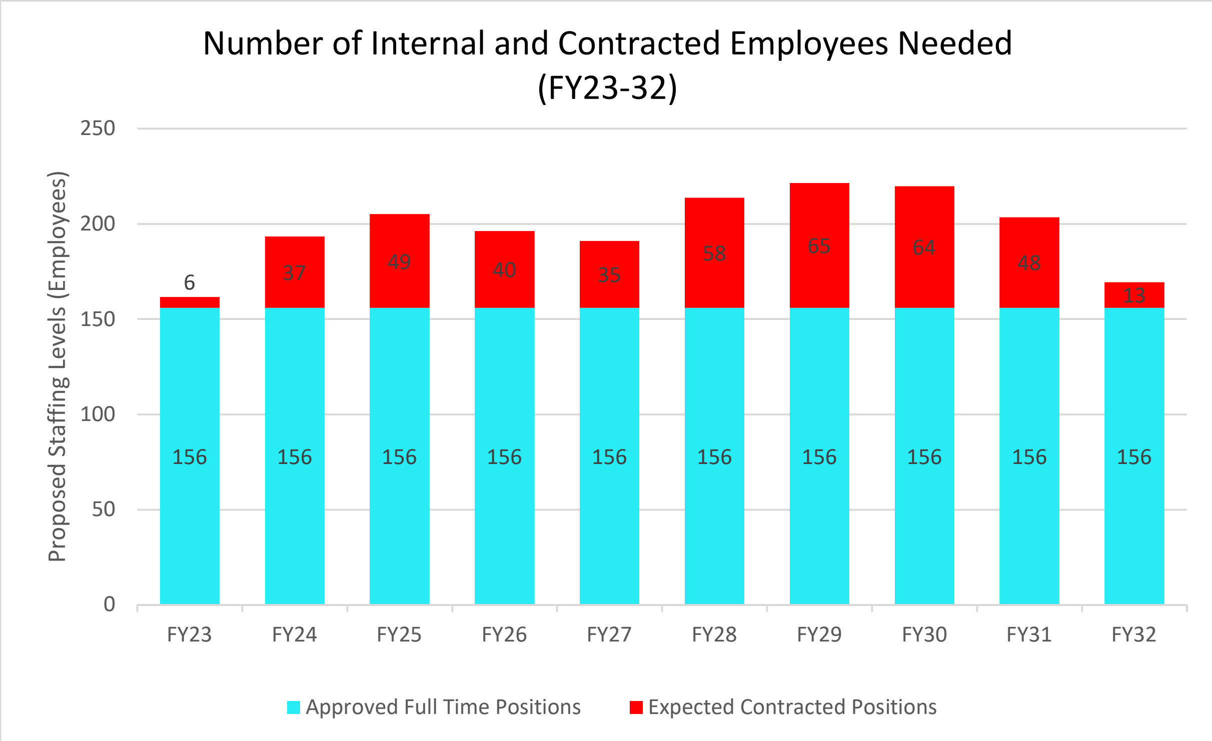


Figure 45: Number of Internal and Contracted Employees Needed (FY23-32)

Another way to visualize the required resources needed to complete the capital budget is shown in the chart below. Major categories such as internal labor, contracted labor, and materials are shown for the first 10 years of the PDMP.

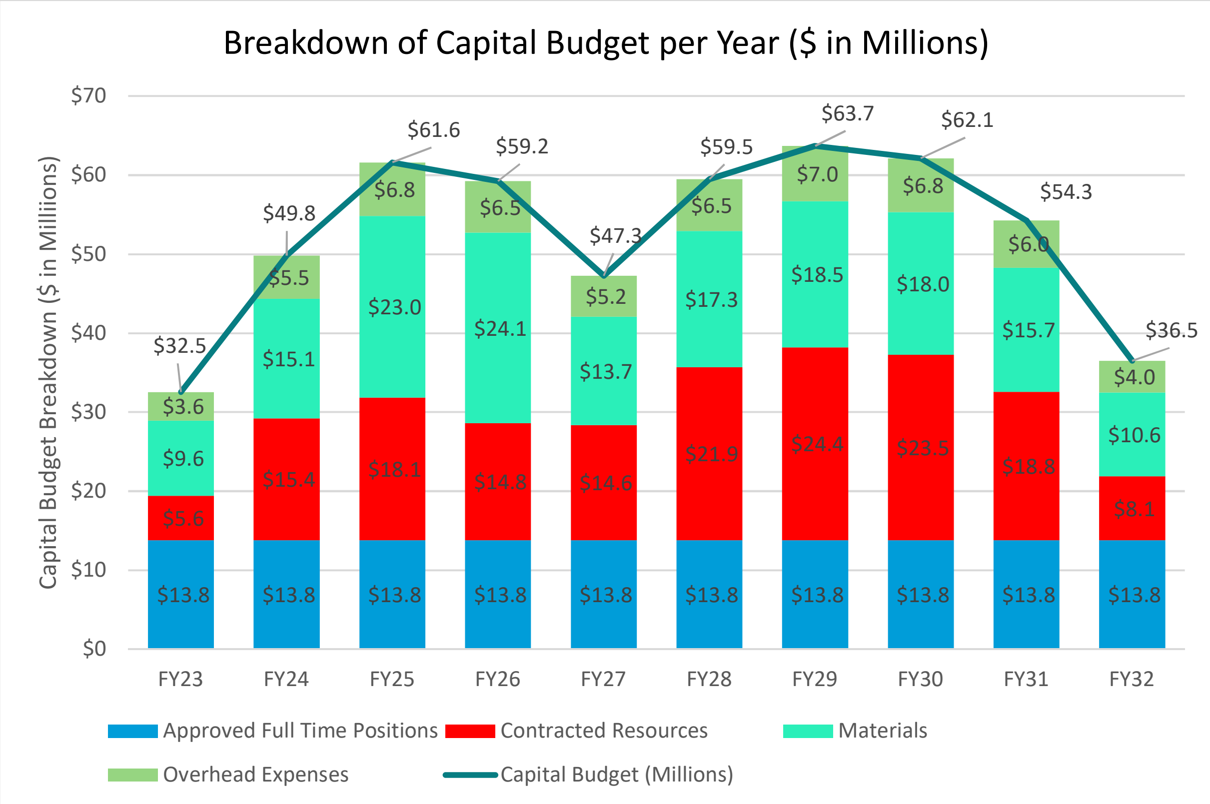


Figure 46: Breakdown of Capital Budget for First 10 Years of PDMP

11.4. Staffing Requirements for Operation and Maintenance

The proposed Capital Improvement Programs will result in new technologies being implemented throughout the distribution system. As the capital improvement projects increase, PWP expects the resource requirement to also increase to support new technologies and equipment being installed throughout the system. For example, smart grid and automation technologies (such as AMI, DMS, and Work/Asset Management) will require staff with special skillsets for their operation and maintenance.

As new technologies and automation are being added to the electric system, special skillsets are needed to properly maintain the automated systems. PWP currently is developing these skillsets, however additional resources may be needed as automation continues to grow. PWP will closely monitor and analyze this requirement and determine if additional internal resources are needed to address this concern. Any additional resource requirements will be presented to the City Council in the future as part of the City's annual budgeting process.

PWP will be mindful of not creating a system that is too difficult to operate and maintain, and will be actively trying to reduce its associated costs when possible. While advanced automation technologies will require staff with IT skills and knowledge to maintain them, they will also potentially reduce operational costs for certain equipment, such as switches which could then be remotely operated by Dispatch team with a click of a button rather than having to send out a crew to manually operate it. Another area to potentially reduce maintenance costs will come from the 4 kV to 17 kV conversions, where PWP can replace multiple 4 kV substation units with one 17 kV unit, reducing the overall number of substation units that need to be operated and maintained.

12. POLICIES, PROGRAMS, AND RATES

PWP, and electric utilities in general, face a wide variety of challenges, threats, and opportunities. Adjusting the current policies, programs, and electric rate structures are strategies which can be used to address many of these issues. Actions must be carefully designed to ensure reliable and safe service at reasonable costs to customers.

The recommendations in this report focus on fair compensation and true value of the utility's service, where PWP seeks to mitigate adverse system impacts derived from these challenges while avoiding potential cost-shifting situations.

12.1. General Recommendations for Asset Replacements/Upgrades

In general, PWP will focus on the following policies when upgrading/maintaining its aging infrastructure to ensure high levels of power quality and reliability to its customers:

- Continue with undergrounding projects to improve safety, reliability, and City aesthetics.
- Conduct condition-based replacements of system assets using a risk based analysis to prioritize equipment replacement programs.
- Replace (if practical) 4 kV aging equipment with 25kV rated equipment so that they can be utilized after the voltage conversion to 17kV.
- Replace existing switches with units capable of being remotely monitored and operated (if practical).

12.2. Reliability Policy Adjustments

12.2.1. Planned Outage Policy Recommendations

PWP's planned outages contribute to approximately half of the total system outages, which create inconveniences to affected customers. A goal for the Master Plan is to reduce that number of planned outages by half. When working on the distribution system, PWP should – when safe, practical and without causing major delays – to combine required works in a specific area to prevent additional planned outages.

12.2.2. Live-Line Work Recommendations

Live-line work is another potential solution for mitigating the requirement for planned outages. This solution involves employing hot-sticking techniques for overhead circuits and load break elbows for certain underground circuits. Hot-sticking techniques would be employed to conduct repair and maintenance work on the overhead distribution lines, which could include repair or replacement of insulators, dampers, or cross-arms. On the other hand, load break elbows are recommended to be operated (when it is safe to do so) while energized on underground circuits, which could include connecting or disconnecting cables to transformers, switchgear, or junctions. This is especially useful for performing maintenance without disturbing the critical portions of the grid.

Live-line work techniques are especially recommended for the 4 kV overhead circuits, being that they may represent a challenge for 17 kV circuits. Because the utility is moving forward with the voltage conversions, PWP should continue investing in workforce training with the goal of having all field crews capable of safely performing live-line work up to 17 kV where possible.

While working on energized circuits, the workforce safety should be of the upmost priority. Some of the main considerations will include providing staff with the proper training and the appropriate safety and fire-rated attire for various work scenarios.

12.2.3. Wildfire Mitigation Plan

The CPUC adopted the current fire threat map in 2018. This map includes three tiers of fire risk areas, which are described as:

- Tier 1: High Hazard Fire Risk Area
- Tier 2: Elevated Fire Risk Area
- Tier 3: Extreme Fire Risk Area

PWP is strongly considering undergrounding the existing high voltage lines within Tier 3 areas to mitigate the risk of wildfire.

If Tier 3 areas are selected to be undergrounded, the projects are expected to be completed in the next five years pending City Council's approval.

Aside from undergrounding, PWP will also mitigate fire risks by enhancing its Vegetation Management Program. PWP is required to comply with Public Resources Code and General Order 95, which requires significantly increasing clearances in the High Fire Threat areas.

PWP will continue to use of covered conductors when an overhead line is being replaced, and actively study and conduct projects to mitigate wildfire threats in "Tier 2" and “Tier 3” areas, as well as the other programs detailed in the Wildfire Mitigation Plan. A summary of the fire threat mitigation strategies are shown in table 36.

Table 36: Summary of Fire Threat Mitigation Strategies

Fire Threat Risks and Mitigation Strategies	
Type of Risk	**Mitigation Measure**
High Wind Event	• Enhanced Design Criteria in the High Fire Threat Areas • Blocking of reclosers during wind events
Vegetation Contact	• Vegetation Management Program
Conductor Failure	• All new overhead construction installs covered wire • Construction Standards • Improved Protection settings • Detailed Overhead Asset Inspection Program
Pole / Hardware Failure	• Detailed Overhead Asset Inspection Program • Enhanced Design Criteria in the High Fire Threat Areas • Construction Standards
Aging Infrastructure	• Enhanced Design Criteria in the High Fire Threat Areas • Construction Standards

12.3. Utility Owned Distributed Energy Resources

PWP should consider installing utility-owned distributed resources nearby or onsite PWP’s substations or throughout the distribution grid. A Distributed Generation program could include installation of renewable generators (such as PV solar systems), installation of utility scale BESS, and a pole-mounted battery storage.

Utility-owned battery storage systems could provide various benefits to PWP such as an improvement in system reliability, reduce peak loads, reduce system losses, eliminate the need for certain power supply contracts, and reduce the amount of capital investments needed to support peak loads. These batteries can either be larger in scale, and thus needed to be installed on PWP’s premises, or can be smaller in scale, and potentially be installed on customer premises.

The smaller installations could be very similar to customer owned BESS, but they would be owned and operated by the utility, and be in front of the customer's meter. Given that the proper controls exist within the inverter, these utility owned BESS solutions could be used to improve customer's reliability in the case of circuit outages, while also providing full functionality for PWP to utilize them to solve distribution overloading issues, as an example. Hypothetically, if a customer were to allow PWP to install a utility-owned BESS on their property, the customer would drastically decrease their odds of having sustained power outages, at no charge to them. PWP would be able to improve both its power resource portfolio, as well as solve certain distribution system issues which may require costly capital upgrades.

PWP should conduct market investigations to evaluate potential vendors and technologies for distributed generation that can be integrated on the distribution grid. PWP should focus on studying potential BESS solutions on its 4kV circuits to mitigate circuit overloading and voltage issues, and to consider generating revenue by bidding these units into the CAISO market for energy arbitrage and resource adequacy.

12.4. Customer DER Regulations

When DERs are small in quantity, size, or concentration, their impact to the power system and local power quality is minimal. However, as customer participation in renewable energy programs increases or as larger renewable power generation sites emerge, the impacts to the distribution system must be regulated to prevent system and power quality problems. Conversely, DERs strategically placed in the distribution system could reduce the need for system upgrades.

Common system issues could be mitigated significantly if PWP requires new customers to install smart inverters on their systems. If managed properly, smart solar inverters will allow PWP to handle higher levels of DER penetration than with standard solar inverters. Smart solar inverters would also provide the utility an interface to get better control over their customers' DER systems behavior to adjust the settings as the more solar is added, and the power system changes.

The distributed generation interconnection requirements should include a strategy to utilize homeowners' smart solar inverters to prevent voltage rise on the circuit. If properly set, a smart solar inverter can facilitate more solar on a given utility circuit. It is recommended that PWP develop a smart solar inverter standard for all of its DER customers, which would require certain features on customer inverters, as well as location specific settings, to prevent voltage issues on the circuit. Furthermore, the smart solar inverters need to have the required compatibility for future programs by

PWP where the utility controls its customer DERs. For current standard DER equipment, PWP engineers can recommend solar inverter settings that are ideal at the time of proposed interconnection.

Figure 47: Pasadena's Arroyo EV Charging Plaza

12.5. Transportation Electrification Program

PWP currently has the highest percentage of registered EVs than any other Southern California utility. Transportation electrification has the potential to increase the energy sales without significant investments since 80% of the charging is done at home and 80% of that charging generally occurs during off peak. Increased sales without the need for significant investment means that the cents/kWh is lower for all customers, not just EV drivers. Therefore, electric transportation energy sales creates a downward pressure on rates for all customers. The key to a successful Transportation Electrification program is to educate and achieve EVs charging at the ideal time – during off-peak hours.

PWP has identified strategies to provide incentives for increasing electric transportation in the City, as it is beneficial to the utility to increase the number of electric vehicles, which help increase energy sales. Additionally, EV charging stations will be priced to consider operation under a time-based rate to prevent peak loads during the day.

A big strategy for PWP to promote electric transportation in the City has been the implementation of EV charging stations. Most of the costs to install new EV charging stations are reimbursed from external sources such as grants and low carbon fuel standard ("LCFS") credits. PWP has completed several EV charging station projects in the last few years, and plans to continue on this trend. With sufficient public infrastructure in place, it opens the opportunity to provide customer EV programs such as a low-income program, a loyalty subscription program, and support for shared mobility (Uber/Lyft), as well as last mile delivery services.

As EV penetration increases and new technologies evolve in the next 20 years, PWP will monitor the potential for vehicle-to-grid (“V2G”) solutions to be implemented.

12.6. Gas-to-Electric Conversion Program

Similar to renewable energy state requirements, building electrification mandates are also a possibility in the future. Building electrification for new construction and conversion (gas to electric) could be promoted to reduce carbon-based fuels and CO2 emissions.

Gas-to-electric conversions can significantly increase system load throughout the day, which will generate revenues for the utility without drastically increasing the peak demand on the system. Electric systems are generally sized to serve the projected peak demand, and systems are considered more cost efficient when their average load is as close to the peak load as possible.

State, federal, and regulatory grants may be available for gas-to-electric conversion studies and retrofit programs. Appliances that can increase electric load includes heat pumps, water heaters, electric cooking stoves, and electric heating. PWP will continue to closely follow initiatives and programs from the state and federal governments, and consider programs and incentives accordingly.

12.7. Cyber Security Policy

PWP has a cybersecurity policy aimed to establish the requirements to protect the City of Pasadena’s low impact Bulk Electric System (“BES”) and Bulk Electric Cyber Systems (“BCS”) in accordance with the North American Electric Reliability Corporation (“NERC”) Standards. BCS are identified through an assessment conducted at least every 15 months to determine the impact rating (low, medium or high) of cyber systems. This policy covers the assets at TMG which operate at 220kV.

PWP needs to continuously update its cybersecurity policy to keep up with developing utility industry standards for the subtransmission and distribution systems. This is very important as PWP implements more and more communication technologies into its system to support grid modernization efforts, it needs to continually assess the effects on both the utility and the customer’s cybersecurity. PWP will continue to revise and update standards for the equipment technologies implemented in the future, and actively track and monitor cybersecurity requirements for any devices that integrates or communicate with PWP network.

All communicating devices, programs, and equipment must comply with the utility's cyber security policy. Policies are updated periodically to further secure network integrity. PWP invests in continual cybersecurity training for staff to ensure personnel are aware of potential threats.

12.8. Interconnection Agreements

Currently, the tie with CAISO's 230 kV transmission system is the only available interconnection to the outside grid used for power transfer to the City. PWP also has an interconnection with LADWP's 35 kV subtransmission system, which is currently solely maintained for emergency events.

The interconnection agreement with SCE at TMG Receiving Station has set the maximum import capacity to 336 MW. However, the operational limit at TMG is capped at 280 MW. Therefore, upgrading this station is highly recommended to meet the contractual import capacity limit, even during N-1 contingencies.

On the other hand, the connection with LADWP's system at the west side of the City – which is normally open - has the capability of delivering up to 40 MW of power at the Glenarm Receiving Stations. A phase shifting transformer is required to maintain permanent the interconnection with LADWP, allowing power to simultaneously be imported from CAISO and LADWP at the same time. The current two St. John 35kV lines are rated to support up to 40MW of load to transfer power to and from LADWP. The lines could be used for economic dispatch, black-start support, peaking beyond the import capacity, west side energy support for capital improvement projects and to assist LADWP with their implementation of the CAISO's Energy Imbalance Market ("EIM") which could have a financial benefit to PWP.

Additionally, a near-term project is in progress to use the St. John lines to mitigate forced rolling blackouts during a CAISO load curtailment event. Should a blackout occur, PWP will be able to maintain electric service to all customers while still fulfilling its obligations for load reductions to the CAISO system.

12.9. State/Health Emergencies

State emergencies can significantly impact daily activities throughout the country, the most recent example being the 2020 worldwide Coronavirus COVID-19 pandemic, which challenged continuity plans, as the City faced Stay at Home orders and workforce disruptions which have never been seen before. PWP's mission of critical operations will be prioritized to maintain business continuity and customers' safety during emergencies.

The goal of this policy should be to ensure safety, reliability, and resiliency of service is provided to the customers. PWP's customers should be a primary concern during emergency conditions. Local maintenance outages should be avoided or reduced as many residential customers could be under state-mandated Stay at Home order.

12.10. <u>Electric Service Rates</u>

PWP's electricity rates will contribute to a sound fiscal system of revenues and expenditures, and are required to be compliant with State legislated mandates (Proposition 26) as well as competitive when compared to neighboring utilities' rates. Future cost of service studies will benefit from data collected through the new CIS and AMI systems once they are completely deployed. The new CIS will enable opportunities for new rate options, which would obtain substantial flexibility once AMI is deployed.

12.10.1. Time of Use ("TOU") Rates

TOU rates are a potential strategic tool to shift load by incentivizing customers to use energy at times when overall demand on the system is lower. PWP currently has a TOU rate structure that is mandatory for large commercial customers. Once AMI is deployed, the collected meter data can be leveraged to design an optimal rate structure that adjusts to the system demand and daily peaks.

Modifying rates are expected to greatly influence customer energy consumption behavior, which will allow the utility to obtain desired system goals and minimize or defer capital improvements. Time-of-use rates will also help incentivize customers to shift their load to non-peak times, which will help improve the load factor, which has been recently deteriorating due to PV system deployment.Net Metering Rates

The net metering tariff will be studied in detail to determine recommendations for the purchase/charging of excess DER generation. Net metering could be beneficial to the utility and should be promoted as existing resource contracts expire. The net metering policy should consider compensation to customers who inject power from their DER systems. The policy should also consider charging customers who are injecting power to the grid when it is detrimental to the system, where excess power injected to the grid can create problems such as overvoltage. BESS can also be implemented to mitigate over-generation problems caused by the customers' DER systems. Net metering policies implemented by PWP will consider updates to California's NEM rules for net metering.

13. CONCLUSION

All things considered, PWP has done a great job at maintaining service and providing exceptional reliability to its customers despite its aging infrastructure. This is demonstrated by its exceptionally high reliability indices for both the frequency and duration of outages. It has performed diligent maintenance programs to maximize the useful life of its assets, at a reasonable cost to the customers. In order to maintain such exceptional reliability performance into the future, while adapting to the changing landscape in both system load and future technologies, PWP needs to complete the proposed projects in the PDMP to ensure system capacity and maximize synergies between initiatives.

PWP will incorporate the projected capital expenditures provided in this plan to determine appropriate funding strategies and present annual balanced capital and operating budgets to the City Council for consideration. The PDMP features much needed projects to increase system capacity, such as the TMG transformer and subtransmission line upgrades, which will allow the City to reliably meet the projected demand of the 20 year forecast. The projects will be synergized when possible to increase the efficiency of resources spent to achieve the PDMP goals. For example, when upgrading the 35 kV subtransmission lines, PWP will accomplish multiple goals at once, including but not limited to: increasing capacity of the subtransmission network, establishing a secondary path for power to flow across town from east to west, upgrading aging cables with new cables, establishing better protection systems and SCADA visibility and control, and matching our import limits.

Furthermore, the PDMP also addresses emerging technologies in the ever changing electric industry. Customers are increasingly adding DER systems to their service, which decrease the overall electric demand on the grid. At the same time, customers who are switching from gas powered vehicles to electric vehicles increase the electric demand on the grid. The net of these two trends will potentially have implications on the electric system's power quality and circuit capacity. PWP will address these changes through continually adjusting its load forecast with new data to account for growth in customer solar, storage, and EVs, as well as continue to invest in its electric vehicle charging stations to facilitate the growth in this industry. Finally, PWP will assess its interconnection agreements periodically to ensure that DERs are selected and operated in an optimized manner, to maximize benefits for both the electric system and the customers.

The PDMP projects will also aim to reduce operations and maintenance costs of the electric system over time. Projects such as AMI, substation and distribution automation, and the SCADA/OMS/DMS upgrades will provide dispatchers enhanced visibility and control of the electric system, and allow them to remotely switch meters/switches reducing truck rolls. Other projects like 4 kV to 17 kV voltage conversions and unit substation upgrades will allow PWP to reduce the amount of physical assets needed to serve its customers, thus reducing the amount of recurring maintenance needed to be done throughout the electric system. At the same time, these projects will allow PWP to upgrade aging equipment with newer equipment, helping PWP meet its asset replacement goals to maintain system reliability.

14. ACKNOWLEDGEMENTS

PWP wishes to Acknowledge and thank the members of City of Pasadena Council, Municipal Services Commission ("MSC"), the Stakeholders Technical Advisory Group ("STAG"), Environmental Advisory Commission ("EAC"), and the staff of PWP for their support and assistance in completing this Master Plan.

Table 37: Key Members of the Stakeholder Technical Advisory Group (STAG)

Name	Affiliation/Company
Felicia Williams	City Council Member
Margaret McAustin	(Former) City Council Member
Julie Gutierrez	(Former) Assistant City Manager
Curtis Edwards	Kaiser Permanente, STAG
John Onderdonk	California Institute of Technology
Morey Wolfson	Resident of Pasadena
Paul Little	Pasadena Chamber of Commerce
Phillippe Gerretsen	Resident of Pasadena
Robert Kurkjian	Pasadena Environmental Advisory Commission
Rollin Homer	Art Center College of Design
Shirley Barrett	Pasadena Unified School District
Tanya M. Geary	LA Live
Tom Romeyn	Huntington Hospital
Kris Markarian	Public Works City Engineer

FIGURES

TABLES

ABBREVIATIONS

A – Ampere

AL – Aluminum

AMI – Advanced Metering Infrastructure

AMR – Automatic Meter Reading

AMS – Asset Management System

ANSI – American National Standards Institute

ATS – Automatic Transfer Switch

BCS – Bulk Cyber System

BES – Bulk Electric System

BESS – Battery Energy Storage System

CAISO – California Independent System Operator

CARB – California Air Resources Board

CIP – Capital Improvement Plan

CIS – Customer Information System

City – City of Pasadena

CPUC – California Public Utilities Commission

CU – Copper

DA – Distribution Automation

DER – Distributed Energy Resources

DGA – Dissolved Gas Analysis

DMS – Distribution Management System

EA – Engineering Analysis

EAC – Environmental Advisory Committee

EIM – Energy Imbalance Market

EM - Electromechanical

EPA – Environmental Protection Agency

EPR – Ethyl Propylene Rubber

ERT – Encoder Receiver Transmitter

ET&C – Electrical Test and Construction

EV – Electric Vehicles

FTE – Full-time Employee

FCI – Faulted Circuit Indicator

GHG – Greenhouse Gasses

GIS – Geographic Information System

GO – CPUC General Order

GW – Gigawatt -= 1,000,000,000 Watts

GWh – Gigawatt Hours

Hz – hertz

IEEE – Institute of Electrical and Electronics Engineers

IOU – Investor Owned Utility

IRP – Integrated Resource Plan

IT – Information Technology

IVR – Interactive Voice Response

JPC – Joint Pole Committee

kcmil -1,000 circular mils (unit of measure of cables)

kV – kilovolt = 1,000 Volts

kW – kilowatt = 1,000 Watts

LADWP – Los Angeles Department of Water and Power

LCFS – Low Carbon Fuel Standard

LTC – Load Tap Changer

MAIFI – Momentary Average Interruption Frequency Index

MDM – Meter Data Management

MOU – Municipal Owned Utility

MSC – Municipal Services Committee

MVA – Megavolt Ampere = 1,000,000 Volt Ampere

MVAR – Megavolt Ampere Reactive = 1,000,000 VARs

MW – Megawatt = 1,000,000 Watts

MWh – Megawatt-Hours

N-0 – Normal (No Equipment Out of Service)

N-1 – Normal Less One Element Out-of-service

NEM – Net Energy Metering

NERC – North American Electric Reliability Corporation

O&M – Operations and Maintenance

OH – Overhead

OMS – Outage Management System

PDMP – Power Delivery Master Plan

PILC – Paper Insulated Lead Cable

PMC – Pasadena Municipal Code

XLPE – Cross-Linked Polyethylene

PWP – Pasadena Water and Power Department

RA – Resource Adequacy

RIG – Remote Intelligent Gateway

RFI – Resettable Fault Interrupter

SAIDI – System Average interruption Duration Index

SAIFI – System Average Interruption Frequency Index

SCADA – Supervisory Control and Data Acquisition

SCD – Short Circuit Duty

SCE – Southern California Edison

SCPPA – Southern California Public Power Association

SF6 – Sulfur Hexafluoride

SPCC – Spill Prevention, Control, and Countermeasure

STAG – Stakeholder Technical Advisory Group

T&D –Transmission and Distribution

TMG – T.M. Goodrich Receiving Station

TOU – Time of Use

UG – Underground

UUD – Underground Utility District

V – Volt

V2G – Vehicle to Grid

W – Watt

WECC – Western Electric Coordinating Council

WOMS – Work Order Management System

Path 1 – 35kV Lines between TMG and Santa Anita

Path 2 – “Crosstown Lines” – 35kV Lines between Santa Anita and Glenarm

Path 3 – “Mini Crosstown Lines” – Secondary path of 35kV lines between Santa Anita and Glenarm

Distribution System – Electrical System operating at 17kV or lower that transfers power from substations to customers

Substation Unit– Each unit consists of two power substation transformers and their related switchgear and protection systems

Subtransmission System – Electrical System operating at 35kV that connects substations together to transfer power

Transmission System – Electrical System operating at 230kV that connects the city to the Bulk Electric System

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