Pacific Gas and Electric Company

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Pacific Gas and Electric Company
300 Lakeside Drive
Oakland, CA 94612

January 16, 2024

Advice 7145-E
(Pacific Gas and Electric Company ID U 39 E)

Public Utilities Commission of the State of California

Subject: **Pacific Gas and Electric Company's Updated EPIC 4 Investment Plan, with Requested Modifications**

Purpose

Pursuant to Ordering Paragraph 6 of Decision (D.) 23-11-086 of the California Public Utilities Commission (Commission) and Article 2 of the Commission's Rules of Practice and Procedure, Pacific Gas and Electric Company (PG&E) hereby files this Tier 2 Advice Letter "2021- 2025 Updated Electric Program Investment Charge (EPIC) 4 Investment Plan."

Background

On November 30, 2023, the Commission issued D.23-11-086 and approved PG&E's EPIC 4 program at $92.685 million with additional requirements that are addressed in this Advice Letter:

1. Demonstrate the alignment between specific Research Topics in its plan and the Commission's Environmental Social Justice Action Plan, the Commission's Distributed Energy Resources (DER) Action Plan, and the federal Justice40 Initiative;
2. Incorporate the modifications and additional requirements specified in Appendix A; and
3. Include:
   i. additional information on its Community Perspectives Advisory Council and how it will demonstrate improved disadvantaged vulnerable California communities (DVCs)/Community Based Organization participation in its workshops,
   ii. a revised equity matrix including only Research Topics that have direct impacts on DVCs that can be substantiated with clear justification in the corresponding Research Topic narratives, and
   iii. details for each applicable Research Topic on how positive impacts on DVCs would be achieved, and/or the likely barriers to their realization.

EPIC 4 INVESTMENT PLAN MODIFICATIONS

PG&E's Updated 2021-2025 Electric Program Investment Charge (EPIC) Investment Plan is provided as two attachments to this Advice Letter: (1) Clean Version, without markups, and (2) Red-Lined Version, with markups. All additional requirements specified in D.23-11-086, and its Appendix A are incorporated into the updated Investment Plan, as reflected in the table below.

Required Modification	Description of PG&E's Modification	Location in Updated Investment Plan
Demonstrate the alignment between specific Research Topics in its plan and the Commission's Environmental Social Justice Action Plan, the Commission's Distributed Energy Resources (DER) Action Plan, and the federal Justice40 Initiative.	PG&E demonstrates alignment between its EPIC 4 Investment Plan Research Topics and the Commission's Environmental Social Justice Action Plan, the Commission's Distributed Energy Resources (DER) Action Plan, and the federal Justice40 Initiative.	Appendixes D, E and F
Appendix A: PG&E shall explain in its Tier 2 AL whether/how there is no conflict or duplication with other transportation electrification activities under D.22-08-024 and D.22-11-040.	PG&E recognizes no duplicative or conflicting activities between D. 22-08-024 and D. 22-11-040 and the transportation electrification technology demonstration work proposed in PG&E's EPIC 4 plan. PG&E will pursue opportunities to share EPIC project outcomes and learnings with teams working on activities related to these two decisions as the outcomes and learnings from EPIC may ultimately serve to be complementary to the objectives and directives in D. 22-08-024 and D. 22-11-040.	Chapter 3 Increase the Value Proposition of Distributed Energy Resources to Customers and the Grid, Transportation Electrification Initiative

Required Modification	Description of PG&E's Modification	Location in Updated Investment Plan
Appendix A: The portion of this Research Topic Area request related to direct air carbon capture is denied. PG&E shall reallocate all funds intended for investigation and demonstration of direct air carbon capture and explain in its Tier 2 AL how the funds will be reallocated.	PG&E has reallocated a portion of the "Climate and Environment Initiative" budget to account for the denial of direct air carbon capture-related scope within PG&E's Research Topic 21 "Climate and Nature-Positive Operations." PG&E will reallocate $500,000 from "Climate and Environment Initiative" to the "Transportation Electrification Initiative." This increased budget will support demonstrations to explore effective pathways to best support vulnerable, disadvantaged and low-income communities with appropriate EV charging solutions.	Chapter 1 Introduction and Background, Strategic Framework and Budget, Table 3: PG&E EPIC Funding 2022–2025
Appendix A: PG&E shall explain in its Tier 2 AL in detail how investment in demonstrating use of carbon credits related to vegetation management and biomass conversion would result in credits that are rigorously demonstrable as real, verified, enforceable, permeant, additional, and robust against leakage.	PG&E explains how the use of carbon credits related to vegetation management and biomass conversion would result in credits that are rigorously demonstrable as real, verified, enforceable, permeant, additional, and robust against leakage.	Chapter 4 Inform California's Transition to an Equitable, Zero-Carbon Energy System That Is Climate-Resilient and Meets Environmental Goals, Research Topic 21 "Climate and Nature-Positive Operations."
Appendix A: PG&E shall explain in its Tier 2 AL how/whether this topic supports early alerts/communications with customers and particularly disadvantaged vulnerable communities during extreme events.	PG&E updates Topic 22 "Disaster Protection" to explain how projects pursuant of this topic can support early alerts/communications with customers and particularly vulnerable, disadvantaged and low-income communities during extreme events.	Chapter 4 Inform California's Transition to an Equitable, Zero-Carbon Energy System That Is Climate-Resilient and Meets Environmental Goals, Research Topic 22 "Disaster Protection"
Appendix A: PG&E shall explain in its Tier 2 AL how safety performance metrics (SPM) and safety and operational metrics (SOM) are well-quantified to ensure that the project is an effective use of ratepayer funds.	Topic 22 "Disaster Protection" Guiding Principles section provides additional information on how projects' safety performance will be monitored and reported.	Chapter 4 Inform California's Transition to an Equitable, Zero-Carbon Energy System That Is Climate-Resilient and Meets Environmental Goals, Research Topic 22 "Disaster Protection," Guiding Principles

Required Modification	Description of PG&E's Modification	Location in Updated Investment Plan
Include i) Additional information on its Community Perspectives Advisory Council and how it will demonstrate improved disadvantaged vulnerable California communities (DVCs)/Community Based Organization participation in its workshops,	PG&E provides additional context on PG&E's Community Perspectives Advisory Council (C-PAC) and explains how PG&E leverages C-PAC membership to increase public workshop participation amongst disadvantaged vulnerable California communities and community-based organizations.	Chapter 5 Administration and Governance, Project Portfolio Governance Process to Leverage EPIC Investments
ii) A revised equity matrix including only Research Topics that have direct impacts on DVCs that can be substantiated with clear justification in the corresponding Research Topic narratives, and	PG&E provides an updated Equity Matrix to include only Research Topics that have direct impacts on DVCs. The Equity Matrix no longer shows "indirect impacts" on DVCs.	Chapter 1 Introduction and Background, Stakeholder Engagement in the Investment Planning Process, Table 2: Equity Matrix
iii) Details for each applicable Research Topic on how positive impacts on DVCs would be achieved, and/or the likely barriers to their realization.	In the corresponding Research Topic narratives, the "Primary Users and Beneficiaries" and "Guiding Principles" sections have been updated to provide additional information on the intended positive impacts within DVCs, as well as identify potential barriers to their realization.	In each applicable Research Topic, Primary Users and Beneficiaries and Guiding Principles

PG&E appreciates the opportunity to provide additional details and revisions to our original EPIC 4 Investment Plan.

<u>Protests</u>

Anyone wishing to protest this submittal may do so by letter sent electronically via E-mail, no later than **February 5, 2024**, which is 20 days after the date of this submittal. Protests must be submitted to:

CPUC Energy Division
ED Tariff Unit
E-mail: EDTariffUnit@cpuc.ca.gov

The protest shall also be electronically sent to PG&E via E-mail at the address shown below on the same date it is electronically delivered to the Commission:

Sidney Bob Dietz II
Director, Regulatory Relations
c/o Megan Lawson
E-mail: PGETariffs@pge.com

Any person (including individuals, groups, or organizations) may protest or respond to an advice letter (General Order 96-B, Section 7.4). The protest shall contain the following information: specification of the advice letter protested; grounds for the protest; supporting factual information or legal argument; name and e-mail address of the protestant; and statement that the protest was sent to the utility no later than the day on which the protest was submitted to the reviewing Industry Division (General Order 96-B, Section 3.11).

Effective Date

Pursuant to General Order (GO) 96-B, Rule 5.2 and OP 11 of D.23-11-086, this advice letter is submitted with a Tier 2 designation. PG&E requests that this Tier 2 advice submittal become effective on regular notice, **February 15, 2024**, which is 30 calendar days after the date of submittal.

Notice

In accordance with General Order 96-B, Section IV, a copy of this advice letter is being sent electronically to parties shown on the attached list [and the parties on the service list for A.22-10-001 and R.19-10-005. Address changes to the General Order 96-B service list should be directed to PG&E at email address PGETariffs@pge.com. For changes to any other service list, please contact the Commission's Process Office at (415) 703-2021 or at Process_Office@cpuc.ca.gov. Send all electronic approvals to PGETariffs@pge.com. Advice letter submittals can also be accessed electronically at: http://www.pge.com/tariffs/.

/S/
Sidney Bob Dietz II
Director, Regulatory Relations
CPUC Communications

Attachments:
Attachment 1 - Updated Pacific Gas and Electric Company
2021– 2025 Electric Program Investment Charge Investment Plan (Clean)
Attachment 2 - Updated Pacific Gas and Electric Company
2021– 2025 Electric Program Investment Charge Investment Plan (Redlines)

cc: Service Lists A.22-10-001 et. al.,
R.19-10-005.

California Public Utilities Commission

ADVICE LETTER SUMMARY

ENERGY UTILITY

MUST BE COMPLETED BY UTILITY (Attach additional pages as needed)

Company name/CPUC Utility No.: Pacific Gas and Electric Company (U 39 E)

Utility type:
☑ ELC ☐ GAS ☐ WATER
☐ PLC ☐ HEAT

Contact Person: Michael Finnerty
Phone #: (279) 789-6216
E-mail: PGETariffs@pge.com
E-mail Disposition Notice to: michael.finnerty@pge.com

EXPLANATION OF UTILITY TYPE
ELC = Electric GAS = Gas WATER = Water
PLC = Pipeline HEAT = Heat

(Date Submitted / Received Stamp by CPUC)

Advice Letter (AL) #: 7145-E Tier Designation: 2

Subject of AL: Pacific Gas and Electric Company's Updated EPIC 4 Investment Plan, with Requested Modifications

Keywords (choose from CPUC listing): Compliance

AL Type: ☐ Monthly ☐ Quarterly ☐ Annual ☑ One-Time ☐ Other:

If AL submitted in compliance with a Commission order, indicate relevant Decision/Resolution #:
D. 23-11-086

Does AL replace a withdrawn or rejected AL? If so, identify the prior AL: No

Summarize differences between the AL and the prior withdrawn or rejected AL: N/A

Confidential treatment requested? ☐ Yes ☑ No

If yes, specification of confidential information:
Confidential information will be made available to appropriate parties who execute a nondisclosure agreement. Name and contact information to request nondisclosure agreement/ access to confidential information:

Resolution required? ☐ Yes ☑ No

Requested effective date: 2/15/24 No. of tariff sheets: 0

Estimated system annual revenue effect (%): N/A

Estimated system average rate effect (%): N/A

When rates are affected by AL, include attachment in AL showing average rate effects on customer classes (residential, small commercial, large C/I, agricultural, lighting).

Tariff schedules affected: N/A

Service affected and changes proposed[1]: N/A

Pending advice letters that revise the same tariff sheets: N/A

[1]Discuss in AL if more space is needed.

Clear Form

Protests and correspondence regarding this AL are to be sent via email and are due no later than 20 days after the date of this submittal, unless otherwise authorized by the Commission, and shall be sent to:

California Public Utilities Commission Energy Division Tariff Unit Email: EDTariffUnit@cpuc.ca.gov	Contact Name: Sidney Bob Dietz II, c/o Megan Lawson Title: Director, Regulatory Relations Utility/Entity Name: Pacific Gas and Electric Company Telephone (xxx) xxx-xxxx: Facsimile (xxx) xxx-xxxx: Email: PGETariffs@pge.com
	Contact Name: Title: Utility/Entity Name: Telephone (xxx) xxx-xxxx: Facsimile (xxx) xxx-xxxx: Email:

CPUC
Energy Division Tariff Unit
505 Van Ness Avenue
San Francisco, CA 94102

Clear Form

ATTACHMENT 1
Updated Pacific Gas and Electric Company 2021– 2025 Electric Program Investment Charge Investment Plan

Pacific Gas and Electric Company

Electric Program Investment Charge (EPIC)

Updated EPIC 4 2021-2025 Investment Plan

January 16, 2024

ACKNOWLEDGMENT

PG&E's Updated EPIC 4 2021-2025 Investment Plan was prepared by PG&E's Engineering, Planning, and Strategy group.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The California Public Utilities Commission (Commission) established the Electric Program Investment Charge (EPIC) in 2011 and renewed the Program in 2020. The Commission's mission for EPIC is to "invest in innovation to ensure equitable access to safe, affordable, reliable, and environmentally sustainable energy for electricity ratepayers." The original EPIC guiding principles were to provide benefits to customers with a focus on safety, reliability, and affordability.

On November 22, 2021, the Commission issued Decision (D.) 21-11-028, authorizing Pacific Gas and Electric Company (PG&E), Southern California Edison Company (SCE), and San Diego Gas & Electric Company (SDG&E), collectively the investor-owned utilities (IOUs) or Utilities, to continue in their role as EPIC program administrators, along with the California Energy Commission (CEC). The Commission further determined that the CEC would continue to receive 80 percent of the budget with the IOUs sharing the remaining 20 percent.

In D.21-11-028, the Commission instructed PG&E, along with SCE and SDG&E, to each file an EPIC Investment Plan Application covering 2021-2025 on October 1, 2022. This period is known as EPIC 4. PG&E's authorized budget for EPIC 4 is $92,685,000, inclusive of PG&E's project and administrative budgets, as well as Commission oversight cost.

PG&E's past and ongoing EPIC projects have provided significant value to its utility customers by facilitating and accelerating the integration of new technologies into the electric grid and into utility operations, and helping to advance the safety, affordability, reliability, and delivery of clean energy to customers. EPIC projects are critical toward helping California achieve its energy and environmental policy goals and support key Commission proceedings.

PG&E's EPIC 4 Investment Plan proposes topics that will continue to drive innovation to support California's progress toward an equitable clean energy future. PG&E's EPIC 4 Investment Plan focuses on advancements toward carbon-neutrality, expanding the potential benefits of distributed energy resources and creating a more resilient grid to impacts from climate change and other emerging threats.

During the development of the IOUs' respective EPIC 4 Investment Plans, extensive stakeholder engagement was conducted. The IOUs jointly held four public workshops, including two public workshops targeted to disadvantaged and vulnerable communities. Additionally, the IOUs provided a joint presentation to the Disadvantaged Communities Advisory Group (DACAG). The IOUs also jointly held numerous discussions to ensure their respective plans avoid unnecessary duplication, while complimenting the CEC's EPIC 4 Plan and the Commission's proceedings. PG&E has incorporated feedback from the DACAG to better embed equity by applying the principles of the DACAG's equity framework to PG&E's EPIC 4 Plan. PG&E has included an equity matrix with our proposed topics and their anticipated direct and indirect equity impacts.

PG&E's EPIC 4 Investment Plan is composed of three areas of strategic investment, called Strategic Objectives. PG&E, SCE, and SDG&E were directed by the Commission to use, as applicable, the Strategic Objectives and Initiatives that are in the CEC's EPIC 4 Investment Plan, as a framework for developing and presenting their own underlying distinct investment topics in their investment plans. Within these three Strategic Objectives, PG&E has proposed to pursue five Initiatives, which are specific opportunities or challenges. Details of how these opportunities or challenges will be operationalized are provided in 23 underlying topics. These Strategic Objectives, Initiatives and Topics are described herein.

Strategic Objective: Create a More Nimble Grid to Maintain Reliability as California Transitions to 100 Percent Clean Energy

PG&E's electric system will undergo substantial changes as it transitions away from reliance on the remaining large fossil-fueled power plants and moves toward a grid dominated by intermittent renewable and distributed generation as well as energy storage systems to deliver 100 percent renewable and zero-carbon electricity. The grid will need to become more flexible, with different resources, and with greater control over when, where, and how much energy flows. EPIC Research, Development and Demonstration (RD&D) will play an important role, both by developing technologies to help maintain electric reliability and resilience and creating modeling and decision tools to identify tradeoffs and optimal deployment strategies for the coming decades. PG&E's topics in this strategic objective are grouped into two initiatives: the Clean, Dispatchable Resources initiative; and the Grid Modernization initiative. The topics within these initiatives will help develop the technologies and modeling capabilities that enable a more flexible electric grid, one that is able to meet our customers' needs, and is reliable, cybersecure, and decarbonized. PG&E is collaborating with the CEC and the other Utility EPIC Administrators as they share this same strategic objective. For certain of the CEC's and PG&E's topics, in particular, PG&E intends to closely collaborate with the CEC on joint projects, working together per our respective roles on the support, development, interconnection, operation, and analysis that will be important for delivering the full benefits of the related research and demonstration.

Strategic Objective: Increase the Value Proposition of Distributed Energy Resources to Customers and the Grid

Distributed energy resources (DERs) are key to achieving California's clean energy goals. DERs have the potential to deliver significant benefits to grid operators and electricity users in a high-renewable, highly electrified future. These potential benefits include load flexibility, peak demand reductions, reducing or deferring grid upgrades and associated costs, improving climate resiliency, grid reliability, and providing compensation to DER owners. There are, however, operational challenges to integrating and maximizing the value of DERs on the grid. The topics in this strategic objective are grouped into the Distributed Energy Resources and Load Flexibility initiative, and the Transportation Electrification initiative. The topics will help develop the technologies and operational capabilities that will improve our understanding of how to maximize the value of DERs to customers and the grid.

Strategic Objective: Inform California's Transition to an Equitable, Zero-Carbon Energy System that is Climate-Resilient and Meets Environmental Goals

As California transitions to an equitable, zero-carbon energy system, PG&E must ensure that the grid is resilient and reliable in the face of climate change, and support California's and its own environmental goals. The EPIC program can be instrumental to providing the sustained investment needed for technology development and demonstration to address the significant challenges ahead to arrive at this future. PG&E's nine topics in this strategic objective are wide-ranging and include new modeling, new and emerging equipment, new inspection and analysis methods, new operational processes, and new ways of interacting with customers. All of these topics are grouped into the single Climate and Environment initiative.

CHAPTER 1: Introduction and Background

Regulatory Background

The California Public Utilities Commission (Commission) established the Electric Program Investment Charge (EPIC) in 2011[1] and renewed the Program in 2020[2]. The Commission's mission for EPIC is to "invest in innovation to ensure equitable access to safe, affordable, reliable, and environmentally sustainable energy for electricity ratepayers."[3] The original EPIC guiding principles were to provide benefits to customers with a focus on safety, reliability, and affordability. On November 22, 2021, the Commission issued D.21-11-028 authorizing the IOUs to continue as EPIC program administrators, along with the California Energy Commission (CEC). The Commission further determined that the CEC would continue to receive 80 percent of the budget with the IOUs sharing the remaining 20 percent of the budget[4]. PG&E's authorized EPIC 4 budget is $92,685,000, inclusive of PG&E's project and administrative budgets, as well as Commission oversight cost. The Commission instructed PG&E, along with SCE and SDG&E to each file an EPIC 4 Investment Plan Application covering 2021-2025 on October 1, 2022[5]. The Commission further directed all Administrators to file EPIC 4 investments plans at the initiative level, and defined initiatives as the strategies EPIC Administrators employ to meet their high-level strategic objectives. EPIC Administrators were also directed to propose funding levels for their initiatives and specify how these initiatives will be operationalized, including the proposed activities[6].

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1. D.11-12-035.
2. D.20-08-042.
3. D.21-11-028, Appendix A.
4. D.21-11-028, Appendix B.
5. D.21-11-028, OP 7.
6. D.21-11-028, OP 8.

This Decision also revised EPIC's Guiding Principles definition of ratepayer benefits to include improving safety, increasing reliability, increasing affordability, improving environmental sustainability, and improving equity. These benefits must accrue to customers and relate to the electric grid.[7] Benefits are discussed within each of the topics in PG&E's EPIC 4 Investment Plan.

Impact of PG&E's EPIC Program

PG&E's EPIC program has provided significant value to its customers through the evaluation, development, and demonstration of new or emerging technologies on the electric grid. PG&E's EPIC 1, 2 and 3 projects have provided customer benefits, which, prior to D.21-11-028, were defined as increased safety, improved reliability, reduced costs, and complementary benefits. These projects have provided additional value by supporting CPUC proceedings, influencing market products, informing industry standards, improving PG&E's GRC requests, and by providing a path to production for promising technologies.

In D.21-11-028, the Commission directed the IOUs to "coordinate with the California Energy Commission and this Commission's Energy Division staff to develop a single, uniform benefits analysis framework and set of metrics that enable the evaluation and tracking of the benefits of all EPIC projects."[8]. The Commission further directed the IOUs to "file a report documenting their success to date of the EPIC projects under its administration, using the metrics they are ordered to create in Ordering Paragraph 12, and in working with this Commission's Energy Division staff."[9] PG&E has coordinated extensively with SCE, SDG&E, the CEC and Commission Energy Division staff to create a common framework for benefits analysis of all EPIC projects. This framework was the basis for PG&E's EPIC 1, 2, & 3 Benefits Impact Report, which summarizes of qualitative and quantitative benefits for all of PG&E's completed EPIC 1 & 2

7. D.21-11-028, OP 2.
8. D.21-11-028, OP 12.
9. D.21-11-028, OP 13.

projects, as well as its active EPIC 3 projects. PG&E's EPIC 1, 2, & 3 Benefits Impact Report is included in this EPIC 4 Investment Plan Application as Appendix C.

Examples of PG&E's EPIC Program successes include the following:

- EPIC 1.01 - *Energy Storage End Uses* introduced the first utility-owned battery storage systems to help establish the California Independent System Operator's (CAISO) new Non-Generator Resource (NGR) market for battery participation and resolved multiple implementation issues with the NGR market model along the way. This served to enable the participation of future storage resources in the market, which now includes PG&E's own Elkhorn Energy Storage system. This project will enable $16 million per year in savings and reduce environmental emissions by 7,000 tonnes of CO_2 per year from PG&E Battery Energy Storage System (BESS) participation in the market.
- EPIC 1.05 - *Demonstrate New Resource Forecast Methods to Better Predict Variable Resource Output* deployed a new meteorological model that drastically improved the resolution of PG&E's weather modeling capabilities from 15km to 3km resolution and provided foundational improvement across a number of applications including winter storm and wildfire risk management. It is estimated that these capabilities enable the avoidance of 15.2 million customer minutes of interruption (CMI) per year and an associated $40.8 million per year in avoided customer economic impact.
- EPIC 1.14 - *Next Generation SmartMeter™ Telecom Network Functionalities*[10] developed the foundation for PG&E's SmartMeter Partial Voltage Detection system, which is now deployed across PG&E's service area. The faster detection of issues across PG&E's system enabled by this technology reduces 8 million CMI per year and provides an associated $22 million per year in avoided customer economic impact.
- EPIC 2.34 - *Predictive Risk Identification with Radio Frequency (RF) Added to Line Sensors* demonstrated Early Fault Detection (EFD) sensors that proved to be highly effective at identifying a wide range of developing asset issues early and pinpointing the geographic

10. SmartMeter is a trademark of Pacific Gas and Electric Company.

locations of the issues with high precision. As a result of the successful demonstration, PG&E has begun working to deploy these sensors on 75 distribution feeders, which is expected to improve operating efficiency and reduce operating costs by $6 million per year.

- EPIC 3.03 - *Distributed Energy Resource Management System (DERMS) and Advanced Distribution Management System (ADMS) Advanced Functionality* developed and deployed a low-cost communication system to allow customers with large DERs to save around a total of $2.25 million per year in sending required telemetry data from their DERs back to PG&E.
- EPIC 3.11 - *Location-Specific Options for Reliability and/or Resilience Upgrades* pioneered multi-customer microgrid capabilities and operationalized the first multi-customer microgrid in PG&E's service area in collaboration with the CEC and numerous other parties. The foundational capabilities developed through this project directly defined the tariff structures and interconnection processes of PG&E's broader Community Microgrid Enablement Program (CMEP) and the Microgrid Incentive Program (MIP), which are now in the process funding the establishment of approximately a dozen microgrids. The associated reliability benefit attributed to this EPIC project is 160,000 CMI per year, corresponding to $3.9 million per year in customer economic benefit.
- EPIC 3.20 - *Data Analytics for Predicative Maintenance* leveraged a range of existing PG&E data sources to develop and deploy an industry-leading analytical model for identifying problems with distribution transformers with a high degree of accuracy. This model has been transitioned directly into operational use, has already led to numerous successful interventions, and is expected to save customers 1.2 million CMI per year and an associated $3.2 million per year in customer economic benefit by preventing outages caused by failed distribution transformers.

PG&E's proposed EPIC 4 Investment Plan will help California achieve energy and environmental policy goals, such as 100 Percent Clean Energy by 2045,[11] 100 Percent Zero-Emission Vehicles by 2035,[12] and Climate Change 2022 Scoping Plan[13]. PG&E's EPIC 4 plan also supports the Commission's key proceedings, such as Integrated Resources Plans[14], Development of Rates and Infrastructure for Vehicle Electrification (DRIVE)[15] and Climate Adaptation[16] to help inform these proceedings with learnings and data from demonstrations.

For the EPIC 4 investment cycle, these important California energy and environmental policy goals and Commission proceedings are represented in PG&E's investment plan as Strategic Objectives. Below, PG&E provides examples of our Strategic Objectives and how key policies and proceedings are supported through potential EPIC 4 advancements:

- PG&E Strategic Objective: Create a More Nimble Grid to Maintain Reliability as California Transitions to 100 Percent Clean Energy
    - Energy Policy Goal: SB 100: 100 Percent Clean Energy by 2045
    - Commission Proceeding: IRP

    This PG&E EPIC 4 Strategic Objective supports California achieving its energy policy goal of 100 percent clean retail energy sales from renewable energy resources by 2045 and the Commission's IRP proceedings to support the transition to delivery of clean energy by continuing innovation to enable reliable, resilient, renewable and affordable clean energy. The following are examples of advancements targeted by

11. SB 100, De León, Chapter 312, Statutes of 2018.
12. Executive Order (EO) N-79-20, 2020.
13. AB 32 requires the California Air Resources Board to develop a Scoping Plan that describes the approach California will take to reduce GHGs. The Draft 2022 Scoping Plan assesses progress toward the statutory 2030 target, while laying out a path to achieving carbon neutrality no later than 2045.
14. R.16-02-007.
15. R.18-12-006.
16. R.18-04-019.

PG&E's topics within this Strategic Objective that support these energy and environmental policy goals and proceedings:

- Ability to store vast quantities of renewable energy for long durations to ensure a reliable, affordable energy supply.
- Integration of emerging renewable generation technologies in a cost-effective, safe, and reliable manner.
- Microgrid technology and operational capability that can help mitigate capacity constraints, accelerate the adoption of new renewable generation and storage resources, and eliminate customer disruptions from PSPS and EPSS events.
- Enhanced system protection that is appropriate for a grid increasingly powered by inverter-based resources.
- Grid scenario planning tools that ensure that, over decades, the grid can evolve at a pace supportive of energy and environmental goals.

- PG&E Strategic Objective: Increase the Value Proposition of Distributed Energy Resources to Customers and the Grid
  - Energy Policy Goal: 100 Percent Zero-Emission Vehicles by 2035
  - Commission Proceeding: DRIVE

  This PG&E EPIC 4 Strategic Objective supports the California statewide target of 100 percent of passenger vehicle, off-road and drayage operation vehicle sales to be zero emission vehicles by 2035, and where feasible 100 percent of medium and heavy-duty vehicle sales to be zero emission vehicles by 2045. A key component of the Commission's DRIVE proceeding is helping the State achieve transportation electrification. PG&E provides the following examples of advancements within this Strategic Objective that support these energy and environmental policy goals and proceedings:

- Ability to quickly and reliably interconnect the large and increasing amount of DERs, to enable transportation electrification and charging infrastructure buildout while avoiding delays associated with traditional capacity upgrades

- Coordination and optimization of DERs by supporting the development of charging infrastructure, integrating EV load/grid support capabilities into grid planning, and working with technology providers to develop EV interoperability standards for the benefit of both customers and the grid.

- Ability to effectively leverage electric vehicles as DERs and grid support resources when connected to the grid

- Reducing the barriers to full transportation electrification, including but not limited to, the availability of a wider variety of EV charging options, the seamless interoperability for advanced V2X use cases, and an increase in the value proposition of EVs for customers through an EV battery second-life pathway.

- PG&E Strategic Objective: Guide California's Transition to an Equitable, Zero-Carbon Energy System that is Climate-Resilient and Meets Environmental Goals
  - Energy Policy Goal: AB: 32, Climate Change 2022 Scoping Plan
  - Commission Proceeding: Climate Adaptation

  This PG&E EPIC 4 Strategic Objective supports the State’s goal to eliminate greenhouse gas emissions and become carbon neutral by 2045 as well as the Commission’s Climate Adaptation proceeding to mitigate environmental impacts from climate change. PG&E provides the following examples of advancements within this Strategic Objective that support these energy and environmental policy goals and proceedings:

  - Demonstration of equipment and analytics technologies that prevent disasters that could result from extreme climate change-induced events.

- Ability to adopt climate and nature-positive operational methods, including, for instance, using the enormous volumes of woody biomass as a carbon sequestration opportunity for renewable natural gas or other value-added products.
- Demonstration of technologies and systems that enable our customers to reduce the environmental impact of their energy usage.

Stakeholder Engagement in the Investment Planning Process

This proposed EPIC 4 Investment Plan was developed through extensive internal engagement and through an open process including two workshops for the general public, two workshops for DAC representative groups, as well as numerous consultation meetings with the CPUC and CEC.

Internal: PG&E conducted extensive internal ideation for its EPIC 4 Investment Plan. First, PG&E solicited and collected hundreds of ideas in an open, bottom-up ideation process across the whole of the enterprise. These ideas were then grouped and aligned with the known technology and operational maturity gaps identified in PG&E's long-range planning and strategy initiatives. Each group of related ideas was then merged into a detailed narrative through an iterative process with the original idea submitters, other Subject Matter Experts (SMEs) and leadership, that ultimately resulted in the topics proposed in this application.

External: PG&E, along with SCE and SDG&E, conducted extensive stakeholder engagement for input on their respective EPIC 4 Investment Plans, including conducting four public workshops. The first public workshops included an initial overview of each Utility's proposed initiatives, presented with thematic panel-led discussions by the Electric Power Research Institute (EPRI)—an independent, non-profit organization recognized as a leader in conducting electric utility industry research and development. The second public workshop provided a more detailed review of each Utility's topics, presented thematically by Strategic Objective. Additionally, the IOUs held two targeted workshops with Disadvantaged Communities (DACs) to discuss how these communities can engage in each utility's EPIC 4 Investment Plan, understand these communities' challenges and priorities for technology innovation, and obtain feedback to inform the IOUs' EPIC 4 Investment Plans.

These workshops, as a whole, were well-attended with a broad spectrum of participants, including academia, industry, and research institutions, as well as environmental, customer advocates and community-based organizations. Table 1 summarizes the names and dates of each workshop.

Table 1: Stakeholder Events Held for EPIC 4 Investment Plan Development

EPIC 4 Public Event Title	**Date**
Joint Utilities EPIC DAC Workshop	June 21, 2022
Joint Utilities EPIC Public Workshop	June 30, 2022
Joint Utilities EPIC DAC Workshop	August 25, 2022
Joint Utilities EPIC Public Workshop	August 29, 2022

The IOUs also reached out to the Disadvantaged Communities Advisory Group (DACAG) and announced the joint IOUs DAC Workshops at the DACAG meetings. On August 19, 2022, the IOUs presented highlights of their draft EPIC 4 Investment Plans and explained how the initiatives would benefit DACs and under-resourced communities. The IOUs incorporated feedback from the DACAG into their second DAC Workshop to expand on how DACs and under-resourced communities can help provide feedback and shape EPIC 4 projects at project public workshops, following Commission approval of the IOUs' respective EPIC 4 Investment Plans.

PG&E has also applied the DACAG's Equity Framework to our EPIC 4 Investment Plan. The DACAG Equity Framework outlines the following key equity principles which have been adapted to our EPIC topics:

- **Health and Safety:** PG&E's EPIC 4 Investment Plan has a number of clean energy resources- and transportation electrification-related topics that will improve air quality for a positive impact on health. The air quality improvement will benefit all customers. Though as PG&E looks for opportunities to site specific demonstrations in DACs, there could also be a more direct, immediate benefit for those hosting communities. A number of topics in PG&E's EPIC 4 Investment Plan also increase resiliency or address climate change vulnerabilities, both of which would result in fewer outages and improve safety.

- **Access and Education:** PG&E encourages adoption of emerging technologies for grid advancement in DAC and under-resourced communities. As PG&E holds workshops for the projects that will result from the topics in its EPIC 4 Investment Plan, PG&E will conduct outreach to diverse stakeholders, help encourage community-based organizations to become key project partners, and support small and diverse businesses. PG&E plans to perform targeted outreach for its EPIC 4 project workshops to create meaningful engagement to help ensure demonstrations are applicable to community interests and responsive to these communities' needs.
- **Financial Benefits:** PG&E's EPIC 4 projects will help advance grid capabilities that provide financial benefits to disadvantaged and low-income communities such as by providing cost savings helping affordability. PG&E will put an emphasis, whenever possible, on locating EPIC 4 projects in DACs and other under-resourced communities to help improve energy equity.
- **Economic Development:** PG&E's demonstrations may support job growth for small and diverse businesses within DACs and under-resourced communities. PG&E's EPIC 4 projects also support economic development through working with diverse vendors as they continue to advance clean, emerging technologies applicable to the grid.
- **Consumer Protection:** Since the EPIC program places limits on the IOUs regarding the types of development and demonstration that can be done with EPIC projects, PG&E's projects do not directly address consumer protection. Nonetheless, PG&E's EPIC projects do indirectly support consumer protection through speeding the adoption of clean energy systems.

Although the DACAG's key equity principles apply to the whole of PG&E's EPIC portfolio, Table 2 specifically identifies which elements of the equity framework each topic is expected to support.

Table 2: EPIC 4 Equity Matrix

Topic #	R&D Topic	Health and Safety	Access and Education	Financial Benefits	Economic Development
1	Microgrid Enablement	●	●	●	●
2	Individual Customer Resiliency	●	●	●	●
3	Long Duration Energy Storage	●	●	●	●
4	Integration of New Generation Technologies	●		●	●
5	Grid Sensing and Communication	●	●		●
7	Advanced Drone Applications	●			
8	Advanced Predictive Maintenance and Failure Cause Analysis	●	●		●
10	System Protection	●			
11	Interconnection Enablement	●	●	●	●
13	Electric Vehicle Charging and Integration Enablement	●	●	●	●
14	Electric Vehicle Battery Re-Use for Stationary Energy Storage	●		●	●
15	Preventing Faults from Causing Ignitions	●			

16	Undergrounding Capabilities	●	●	●	●
19	Risk Modeling Improvements	●			
21	Climate and Nature-Positive Operations	●	●		●
22	Disaster Protection	●			
23	Granular Attributes for Environmental Commodity Tracking	●			

Legend for Equity Principles:
● = Direct Benefits

Through the extensive public engagement and the ongoing collaboration amongst the four EPIC Administrators, it became clear that the Administrators' plans proposed to address many related challenges and opportunities. Now that, in the EPIC 4 cycle, the IOUs' plans are no longer being filed at the detailed project level, and instead being filed as sets of higher-level topics, this is to be expected, as there are similarities among the IOUs in the architecture and operation of their systems, the challenges they face, the overarching state goals they are accountable for addressing, and their associated technology development and demonstration needs. Topic areas that overlap are broad and will require a range of solutions that warrant numerous technology demonstrations, and the Administrators will coordinate closely in their project planning to ensure that individual projects avoid unnecessary duplication, ensure robust information sharing, and complement related activities.

Strategic Framework and Budget

Throughout 2022, PG&E developed a strategic framework to help guide the planning for its EPIC 4 Investment Plan. The framework consists of three strategic objectives. The strategic objectives and five associated underlying initiatives are a subset of those in the CEC's EPIC 4

Investment Plan and are the framework under which PG&E's 23 distinct investment topics have been proposed.

The EPIC strategic framework seeks to:

- Guide PG&E's planning and implementation of its EPIC program through the remainder of this investment plan cycle.
- Communicate a consistent set of priorities to stakeholders.
- Illustrate how projects funded through EPIC are building toward an electricity system that meets state energy policy goals.
- Help simplify strategic alignment of PG&E's EPIC investments with its fellow EPIC Administrators, as well as other public energy research programs and policies.

Chapters 2 through 4 of this investment plan provide an overview of each strategic objective and associated initiatives. These chapters then describe PG&E's 23 underlying RD&D topics proposed for funding through the EPIC 4 investment plan cycle. Our three strategic objectives and five initiatives for EPIC 4 are listed Table 3 below. Table 3 also provides the proposed budget allocation for EPIC 4 funding at the initiative level, as well as the proposed administrative budget and PG&E's portion of the oversight budget to be remitted to the CPUC.

PG&E does not have uncommitted EPIC 3 program funds with which to offset its EPIC 4 program budget.

Table 3: PG&E EPIC Funding 2022–2025

Funding Item	**Amount**
Strategic Objective: Create a More Nimble Grid to Maintain Reliability as California Transitions to 100 Percent Clean Energy	
Initiative: Clean, Dispatchable Resources	$18,000,000
Initiative: Grid Modernization	$18,000,000
Strategic Objective: Increase the Value Proposition of Distributed Energy Resources to Customers and the Grid	
Initiative: Distributed Energy Resource Integration and Load Flexibility	$18,000,000
Initiative: Transportation Electrification	$11,453,075
Strategic Objective: Inform California's Transition to an Equitable, Zero-Carbon Energy System That Is Climate Resilient and Meets Environmental Goals	
Initiative: Climate and Environment	$17,500,000
Administration and Oversight	
CPUC Oversight Budget	$463,425
PG&E Administrative Budget	$9,268,500
Total	**$92,685,000**

CHAPTER 2: Create a More Nimble Grid to Maintain Reliability as California Transitions to 100 Percent Clean Energy

PG&E's electric system will undergo substantial changes as it transitions away from reliance on the remaining large fossil-fueled power plants and moves toward a grid dominated by intermittent renewable and distributed generation, as well as energy storage systems, to deliver 100 percent renewable and zero-carbon electricity. The grid will need to become more flexible, with different resources, and with greater control over when, where, and how much energy flows.

EPIC RD&D will play an important role, both by developing technologies to help maintain electric reliability and resilience and creating modeling and decision tools to identify tradeoffs and optimal deployment strategies for the coming decades. The topics described in the chapter fall under two initiatives: Clean, Dispatchable Resources; and Grid Modernization. The topics will help develop the technologies and modeling capabilities that will enable a more flexible electric grid, that is able to meet our customers' needs, reliable, cybersecure, and decarbonized. PG&E is collaborating with its fellow EPIC Administrators as they share this same strategic objective. For certain of the CEC's and PG&E's topics, PG&E will closely collaborate with the CEC and potentially conduct joint projects, working together per our respective roles on the support, development, interconnection, operation, and analysis that will be important for delivering the full benefits of the related research and demonstration.

Clean, Dispatchable Resources Initiative

Clean, dispatchable resources will be foundational to achieving PG&E's and California's clean energy and environmental goals. Microgrids are a key technology area as they offer services to both customers and to the grid, providing reliability, resiliency, capacity constraint mitigation, and emissions-free electric service. In particular, individual customers with critical power needs or that are most affected by PSPS and EPSS events are in need of increased resiliency. Long duration energy storage at a lower cost and of greater size will also be key to delivering clean, dispatchable power throughout the year and through extreme climate conditions. In addition, PG&E needs to learn how to interconnect, and then safely and efficiently operate new types of emerging generation technologies.

1. Microgrid Enablement

Innovation Need

Microgrids offer promising solutions for California electric customer needs—they can make electricity service for remote areas significantly more reliable, reduce or eliminate disruptions caused by PSPS and EPSS events, help mitigate capacity constraints, provide emissions-free service, and in some instances also reduce wildfire risk. While PG&E has begun to develop foundational microgrid capabilities through its EPIC 3 program, many technical issues remain unresolved, including the protection schemes for various microgrid topologies, incorporation of EVs and temporary mobile batteries, alternate generating sources and settings (fuel cells, EVs, new energy storage technology, hydrogen-fueled gensets, etc.), islanding and synchronization, repeatability, and flexibility of microgrid location (within the feeder geographical space as well as service to DACs and critical areas within the grid). Recognizing the forthcoming dominance of renewable energy resources as a microgrid power supply suggests that safely and reliably operated microgrids, in all their different topologies, will be critical for PG&E and the state of California to meet their goals.

Description

Presently, every microgrid is a unique design, and not repeatable. To help create repeatable designs, PG&E will first define a set of microgrid architectures that accommodate the bulk of the current and emerging microgrid needs, defined by, for example, purpose, size, generation and storage types, interconnection type, interconnection location, islanding type and duration as well as load de-energization and critical loads supported. The microgrid designs will then be modeled, followed by laboratory testing of new components or new applications of existing components. Finally, one or more of the microgrid designs will be constructed, permitted, and demonstrated to the satisfaction of PG&E's operations staff and the microgrid owners.

PG&E will seek definitive answers on the following:

- Criteria for when to create a permanently islanded (remote grid), including down to the size of a single residential customer
- Analysis of where microgrids would be most beneficial to reducing localized grid stress
- How to best mitigate the growing power quality and harmonics issues from increasingly inverter-based resources in microgrids
- Black start capability of inverter-based microgrids
- How best to leverage behind-the-meter (BTM) generation, storage, and load curtailment in microgrid operation
- How customers can be compensated for supporting the microgrid through their BTM generation and storage, as well as for responding to load curtailment requests.
- How to best communicate to get settlement-quality metering data from BTM inverters and storage
- Where and how to build microgrids at various locations on a feeder, from the end of the feeder up to and including at a substation
- How to best operate the grid through all of the states of the connected microgrid, including intentional and unplanned islanding, the operation of the microgrid including front-of-the-meter (FTM) and BTM resources
- Alternative clean generating sources and settings for the microgrid use case
- How mobile batteries (including but not limited to mobile batteries on PG&E service trucks) should be best utilized to connect into the pre-existing interconnection hubs on microgrids for islanded grid support during PSPS, EPSS, or other grid outage scenarios.
- When and how to incorporate novel wireless power transmission capability into microgrids, for emergency or permanent use
- When and how to create a service-transformer-located multi-customer microgrid

The fellow EPIC Administrators have begun coordinating and will continue coordinating on activities in this broad area to ensure demonstration coverage of promising microgrid types and technologies, to avoid duplication, and to ensure effective information sharing. In addition, beyond conducting its own projects on various microgrid architectures and technologies through this topic, PG&E will potentially partner with the CEC to conduct joint projects, in which the CEC's projects fund the development and configuration of the microgrid, and corresponding PG&E projects focus on enabling the integration and testing of the microgrid. This model has already proven to be successful in the microgrid space, where PG&E and the CEC executed complementary projects to operationalize the Redwood Coast Arcata Microgrid (RCAM), the first multi-customer microgrid in PG&E's service area.

Expected Outcomes

This topic will provide the following outcomes:

- A playbook of standardized microgrid designs that would help speed implementation and interconnection
- Understanding of how to safely and reliably operate the various standardized microgrid types
- Enhancements to the microgrid equipment test lab at PG&E's Applied Technology Services (ATS) facility to enable testing of the various microgrid designs
- Evaluations of new and/or novel equipment required to safely support the various new and emerging topologies, such as reclosers/controllers, inverters, new meter technology, FTM energy storage including temporary energy storage, as well as BTM generation, storage including EVs, and load control systems
- Confidence in new and novel microgrid-appropriate generating technologies, such as hydrogen or propane-based generation
- Confirmation of system protection configurations and operating parameters
- Deep knowledge of microgrid impact on the PG&E distribution grid and matching mitigation measures through modeling
- Installation, integration, and demonstration of one or more microgrids incorporating new or novel technologies

Metrics and Performance Indicators

- Number of standardized microgrid topologies

- Number of days from inception of new microgrid to permitted operation

Primary Users and Beneficiaries

- **Customers** will benefit from the ability to have reduced PSPS, EPSS, and other grid outage durations, and increased reliability due to microgrid implementation.
- **IOUs** will benefit by advancing customer choice in generation and satisfying a pent-up need for more rapid deployment of microgrids.
- **Grid operators** will benefit from this topic by playing a large role in moving towards standardizing the operational expectations of all topologies of microgrids.
- **Regulators and planners** will benefit by getting an increasing amount of low-carbon generation onto the grid. Planners will benefit by a deeper understanding of the system requirement for widespread deployment of microgrids.
- **Disadvantaged and under-resourced communities** in the wildland urban interface will benefit from improved reliability and safety as PG&E will target such vulnerable, disadvantaged or low-income communities for demonstrations.
- **Technology developers and manufacturers** will benefit from the trialing of new technologies appropriate for microgrid customer acceptance.

Guiding Principles

- **Safety:** Uninterrupted power provided by a microgrid during times of PSPS, EPSS, and other outages avoids unsafe situations that can arise from lack of power.
- **Reliability:** Reliability is enhanced by the ability to island which reduces or eliminates the impact of PSPS, EPSS, and other grid outages.
- **Affordability:** Delivering common microgrid designs with a complete understanding of siting issues with regard to the grid will deliver lower-cost solutions to microgrid owners.
- **Environmental Sustainability:** Most participants in the microgrid market (suppliers, customers, communities, utilities) base their microgrid design on providing renewable energy.

- **Equity:** DACs, vulnerable, and under-resourced communities in the wildland urban interface will benefit from demonstrations targeted for those locations. Uninterrupted power provided by a microgrid during times of PSPS, EPSS, and other outages avoids potential loss of healthcare, education, childcare, and work. This type of energy resiliency can have positive impacts on health and safety, access and education, financial benefits, and economic development.

Background, Previous Research, and Technology Trends

The Redwood Coast Airport Microgrid (RCAM) funded through complementary PG&E and CEC EPIC 3 projects provides an excellent template for understanding how to advance the state of the art for a broader set of use cases. That project paired two groups (the Owner/Operators of RCAM and PG&E) who were committed to working together in full recognition that there would be many complex issues to resolve. Microgrids are not uncommon in the United States, but still make up a very small fraction of the overall generation. The number of configurations is also currently quite small and each microgrid requires extensive custom design, engineering and testing efforts. To increase the pace of deployment, key technical issues such as generation supply, islanding protocols, system protections, coordination of conventional generation with inverter-based generation need to be addressed. Resolving these issues provides a pathway to standardization, which will dramatically increase the pace of microgrid installations.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	●
Generation	●
Transmission	
Distribution	●
Demand-Side Management	●

2. Individual Customer Resiliency

Innovation Need

In response to increasing wildfire risk in recent years, PG&E has formalized a program for implementing Public Safety Power Shutoffs (PSPS) in high fire threat areas within its service area when wind and other environmental conditions exceed pre-defined risk thresholds. In 2021, PG&E also began broadly modifying the settings and increasing the sensitivity of its existing protective devices through its Enhanced Powerline Safety Settings (EPSS) initiative, to automatically de-energize powerlines when potential problems are detected. EPSS operates under a far broader set of environmental conditions as compared to PSPS, including on "blue sky" days. While PSPS and EPSS significantly reduce wildfire risk, they also result in increased outages for customers, and sometimes, a series of unplanned outages for groups of customers over the course of a wildfire season. PSPS outages tend to be longer than EPSS outages, however the unplanned nature and frequency of EPSS outages can be very disruptive to customers.

While PG&E has focused several customer programs on providing commercially available reliability solutions that reduce customer impacts of PSPS and EPSS for a small number of individual customers using Distributed Energy Resources (DERs), there is a need to demonstrate new innovative, scalable, clean technologies as well as the ancillary tools to support the technologies, and address deployment barriers.

Description

This topic will conduct technology demonstrations and path to production activities for a range of clean mobile and stationary DERs to provide greater resiliency at lower costs for individual residential and non-residential customers impacted by PSPS and EPSS events. The work within this topic will focus on three areas:

1. Resiliency DER Technology Development: Enhancing the availability of clean mobile and stationary distributed energy resources (DERs) that can be used to support individual customer resiliency.

2. Resiliency DER Ancillary Tools: Demonstrating innovations in the ancillary tools needed to deploy Resiliency DERs, as well as provide the foundation for enabling multiple other uses and enabling broader benefits. Ancillary tools will include things such as controls, meter connection, and automatic transfer switches.
3. Broader Operational Considerations: Enabling opportunities and addressing barriers to leveraging Resiliency DERs to provide additional value to the energy grid and to customers. Work in this area will be coordinated with Topic 12, “Advanced Distribution Power Flow Management”. Enabling broader value streams will help to accelerate adoption of vehicle and building electrification and enable Resiliency DERs to help support energy affordability for all Californians.

This topic could directly benefit more than one million of PG&E’s electric customers. It will explore solutions and challenges for a range of use cases by type of customer, and frequency and duration of outage impacts that need to be mitigated.

Residential customers impacted by outages include customers living in single family homes, multifamily complexes, mobile home parks and other residences. Examples of non-residential customer types that would benefit from the results of this topic include critical facilities customers, including K-12 schools, gas stations, grocery stores, food banks, and local public safety, medical, and other critical infrastructure[17].

The optimal solutions may be combinations of technologies that vary by use case and customer type. For example, the best solution for customers affected by more frequent but shorter EPSS impacts may differ from the best solution for those affected by less frequent but longer PSPS impacts. The solutions may also be for a PSPS or EPSS event or for a single season until other mitigations can be applied. The best solution will also depend on the types of BTM DERs customers may already have.

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17. PG&E Critical Facility Customer Fact Sheet: https://www.pge.com/pge_global/common/pdfs/safety/emergency-preparedness/natural-disaster/wildfires/CWSP-Critical-Facility-Customer-Fact-Sheet.pdf.

For all the solutions to be demonstrated, the primary purpose is to provide individual customer resiliency, though grid support could also be provided to further increase the value proposition of the DERs to customers. This work will be coordinated with the work in other topics, such as what has been proposed through Topic 12, “Advanced Distribution Power Flow Management”. Topic 2, “Individual Customer Resiliency”, would also explore how the potential increase in value to the customer of also using their Resiliency DERs for other grid support use cases could make adoption more economically viable, thus helping to speed customer resiliency improvements in aggregate.

Expected Outcomes

The following are outcomes expected to result from the demonstrations conducted through this topic:

- Technology Development
    - Operational demonstrations of various combinations of temporary and permanent resiliency DERs with limited sets of customers
    - Testing and evaluation of new battery and clean generation technologies for the resiliency use case
    - Improvements to existing product offerings based on field demonstrations
    - Benchmark various DERs– performance, safety, construction, and battery cell quality for both portable and permanent battery storage
- Ancillary Equipment
    - Identification, operational investigation including for liability considerations, and demonstration of innovative and emerging resiliency use case solutions such as backup power transfer meters, smart panels, microinverters, smart thermostats, load control, and vehicle-to-building (V2B) equipment
    - Reductions in installation and deployment costs
- Deployment Support
    - A playbook for how to package solutions for the various customer use cases

- Recommendations for updates to standards and work methods needed for the safe application and operation of these solutions
- Understanding of the costs and benefits of these solutions per use case in comparison to potential alternatives
- Identification of opportunities to leverage non-ratepayer funding (federal, state) to increase deployment and support affordability
- Understanding of operational considerations of using mobile battery technology (EV) as a backup power source for a customer's dwelling on thresholds of charge to maintain on the EV in case they need to evacuate

Metrics and Performance Indicators

- Percent of customers that experience PSPS and EPSS events that are made invisible to customers through the various solutions demonstrated through this topic
- Number of aggregated kWh available
- Number of solutions for particular use cases successfully demonstrated and included in customer incentive programs
- Cost per customer mitigation across various customer types to enable cost-effective mitigations
- Tons of emissions that could be avoided through the deployment of the solutions demonstrated through this topic by offsetting non-clean generation and providing reliability benefits

Primary Users and Beneficiaries

- **Customers** in high fire risk areas will benefit from improved reliability and lessened impact or elimination of impact from PSPS and EPSS events. This includes but is not limited to customers who have electricity-dependent medical equipment. Leveraging customers resiliency solutions for multiple uses may also reduce costs, supporting energy affordability for all customers. Customers may also benefit from lower local emissions from reduction or elimination of fossil fuels generators operating in the area.

- **IOUs** will have additional solutions to offer their customers to mitigate the impacts of the PSPS and EPSS initiatives they implement.
- **Local governments** will have increased resiliency in critical facilities and lower electrical-outage-related service calls (medical, public safety-related) and lowered impact on local business and residents from power outages.
- **Under-resourced communities** in high fire risk areas will benefit from improved reliability and lessened impact of PSPS and EPSS events.
- **Technology developers and manufacturers** may improve their product offerings based on the results and learnings of the demonstrations.

Guiding Principles

- **Safety**: Reduction of the risk of fire from improperly connected customer fossil fuel generators and customer-supplied portable lithium batteries subject to thermal runaway. In addition, a reduction of the hazards of localized pollution from gasoline or diesel generators, and prevention of back feeding of energy onto the grid from unauthorized installations.
- **Reliability:** The innovative technologies demonstrated in this project will help to lessen the individual customer outage impacts of PSPS and EPSS events.
- **Affordability:** Pre-packaged, repeatable solutions at the right size to fit the use case will reduce customer costs.
- **Environmental Sustainability:** The innovative technologies demonstrated in this project will provide clean alternatives to diesel generators widely used for customer resiliency.
- **Equity:** The innovative technologies demonstrated in this project will help to lessen the outage impacts to specific communities of customers in high fire risk areas that are disproportionately impacted by PSPS and EPSS events. Localized pollution impacts from diesel generation would be eliminated. Additionally, uninterrupted power provided by DERs and mobile clean energy sources during outages avoids potential loss of healthcare, education, childcare, and work. This type of energy resiliency can have positive impacts on health and safety, access and education, financial benefits, and economic development.

Background, Previous Research, and Technology Trends

PG&E and other entities offer a variety of resiliency programs that provide customers resiliency solutions through portable or permanent solutions. PG&E also provides temporary generation to critical customers, as described in its Wildfire Mitigation Plan. PG&E has also worked with a variety of solutions to reduce the costs and increase the viability of Resiliency DERs including the Backup Power Transfer Meter (BPTM) that PG&E developed and piloted for diesel generator backup, and a variety of efforts that explored smart panels and other tools to help customer resiliency. At the same time, Virtual Power Plants (VPP) and other interventions have demonstrated the ability of DERs to provide grid reliability.

However, there are a large number of customers that are not able to be mitigated due to outages, due to the size of their load, restrictions around their premise (for example renters) and the lack of resources (financial and others). This topic will build on existing knowledge to accelerate solutions that can meet the significant needs around customer resiliency and grid reliability in the face of accelerating climate change to enable scalable deployment of clean resiliency solutions to a much larger number of customers.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	**Topic Applicable**
Grid Operations/Market Design	●
Generation	
Transmission	
Distribution	●
Demand-Side Management	●

3. Long Duration Energy Storage

Innovation Need

Advancements in long duration energy storage (LDES) technologies, defined as having a minimum discharge duration of eight hours or longer, are required to maintain reliability and affordability as the state transitions to a 100 percent renewable, zero-carbon electricity system. The capacity challenges California faced in each of the past three summers reinforced the urgent need for additional LDES resources. The CPUC estimates that California will need 1,000 MW of LDES resources by 2030 and the 2021 SB 100 Joint Agency Report[18] indicates that by 2045 the state may potentially need upwards of 4,000 MW of additional LDES resources. LDES, which can discharge over days, weeks, or even seasons, is expected to not only address some of the issues created by weather patterns for which short duration energy storage is insufficient or cost-prohibitive, but also to balance long-term variations in renewable generation created by large weather patterns and changing seasons. Additionally, LDES resources could potentially be used to provide local resilience during extended grid outages.

Apart from conventional pumped hydroelectric storage ("pumped hydro"), neither the technologies nor the business models of other LDES solutions have been proven ready as grid-scale resources. Pumped hydro faces challenges in permitting and has limited potential for expansion due to a lack of suitable sites in California. In recent years, the CEC and other entities have funded the development of a wide range of LDES technologies. Many of these technologies have matured and begun to show viability in lab demonstrations as well as in limited operational behind-the-meter (BTM) demonstrations at customer facilities. Building from previous laboratory and limited BTM field testing of promising LDES technologies, additional demonstration activity is required for PG&E to develop practices and experience to safely interconnect and integrate larger-scale front-of-the-meter (FTM) LDES deployments.

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18. SB 100 Joint Agency Report: Charting a Path to a 100 percent Clean Energy Future. California Energy Commission. https://www.energy.ca.gov/news/2021-03/california-releases-report-charting-path-100-percent-clean-electricity.

Description

This topic will support the FTM installation, demonstration, and grid integration of various LDES solutions that enable the storage of renewable energy for discharge durations of eight to hundreds of hours or longer, and inform resource planning, characterize safety profiles, and provide knowledge of integration and operational considerations. PG&E will focus on demonstrating promising, scalable LDES solutions that have matured and successfully progressed through preliminary lab demonstration through the CEC's EPIC program and elsewhere. Examples of the types of LDES solutions that may be demonstrated include flow batteries, kinetic, thermal, compressed air, liquid air, hydrogen produced from renewable energy, and gravity storage. Prior to interconnecting LDES systems to the grid, PG&E may first validate their operational performance capabilities including discharge profiles, differences from short duration energy storage systems, and compare the systems' relative strengths and weaknesses at its Applied Technology Services (ATS) lab facilities to down-select systems for demonstration on the grid and develop grid integration plans.

Demonstration of use cases will include firming of intermittent renewable generation, providing resilience during PSPS or EPSS events and other grid disruptions, and market participation for energy arbitrage (i.e. flattening the "duck curve"[19]). PG&E would support CAISO and other stakeholders in establishing the framework and technical requirements to enable properly incentivized LDES market participation. PG&E will consider selecting sites for demonstrations that will allow for the co-location of LDES systems with existing intermittent renewable generation, as well as potentially other sites that are better suited to specifically mitigating the effects of PSPS and EPSS outages.

The fellow EPIC Administrators have established bi-weekly coordination meetings on LDES and other technology areas that have significant opportunities for collaboration. Through these meetings, the EPIC Administrators share information on past projects and future investment priorities. Furthermore, the EPIC Administrators are evaluating opportunities and process requirements for formal partnerships on projects and to avoid duplication. For example, PG&E

19. https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf.

and CEC could potentially conduct joint projects in which CEC EPIC funding supports LDES technology development, acquisition, and configuration with PG&E EPIC funding supporting testing and grid interconnection in ways that are safe, replicable, and scalable. Additional strategies include identifying specific demonstration site locations based on PG&E knowledge of local grid conditions and needs prior to the CEC releasing competitive bid solicitations for technology demonstrations. This model for CEC and PG&E collaboration has proven successful in the microgrid space, where PG&E and the CEC executed complementary EPIC projects to operationalize the Redwood Coast Airport Microgrid (RCAM), the first multi-customer microgrid in PG&E's service area.

Expected Outcomes

Expected outcomes from the demonstrations pursued within this topic include:

- Definitive assessment of the readiness, safety profiles, and interconnection considerations of various LDES solutions for FTM grid deployment at scale
- Selection of a subset of solutions for FTM demonstration
- Installation, integration, and operational safety testing of one or more LDES systems
- Transfer of installed systems to steady-state post-EPIC operations, with post-EPIC funding
- Development of a roadmap, strategy, and implementation plan for broader future Utility and/or third party LDES acquisition, deployment, and grid integration

Metrics and Performance Indicators

- Demonstration of safe and reliable operation of LDES systems
- Number and total MWh of LDES systems successfully installed on the grid and transitioned to steady-state post-EPIC operations
- Availability of standardized market models and integration methods for LDES

Guiding Principles

- **Safety**: This topic will demonstrate LDES technologies that eliminate or mitigate safety risks such as thermal runaway.

- **Reliability**: LDES can play a critical role in ensuring electric reliability across long periods of low renewable generation and even across seasons.
- **Affordability**: Demonstration of emerging LDES technologies will target cost reductions that support electric service affordability.
- **Environmental Sustainability**: Implementation of non-lithium-ion storage technologies can increase supply chain diversity, reduce reliance on critical materials, and prove end-of-life recyclability or benign disposal.
- **Equity:** Reliable electricity supply, supported by long duration energy storage during outages, avoids potential loss of healthcare, education, childcare, and work. This type of energy resiliency can have positive impacts on health and safety, access and education, financial benefits, and economic development.

Primary Users and Beneficiaries

- **Customers** will benefit from the reliability benefits that LDES provides in the transition to a 100 percent renewable and zero-carbon energy grid, as well as the financial benefits of energy price arbitrage through LDES market participation.
- **IOUs** will benefit from solutions that will enable them to maintain affordable and reliable service in a transition to a 100 percent renewable and zero-carbon energy grid.
- **CAISO** will benefit from advancements in larger-scale FTM LDES technologies that mitigate potential generation shortages and operational challenges due to the seasonal variability of wind and solar.
- **Regulators and planners** can use the results from this topic to integrate LDES assets within grid planning and procurement decisions to achieve state energy goals.
- **Policymakers** can use the results from this topic to assess the effectiveness of policies to retire remaining fossil fuel generation, increase the use of renewable energy to meet SB 100 goals, and reduce total system costs.
- **Technology developers and manufacturers** will benefit from targeted opportunities to demonstrate, improve, and build market confidence that their technologies enable safe, reliable, affordable electric service with reduced environmental impacts.

Background, Previous Research, and Technology Trends

While energy storage is one of the fastest growing markets in the world, lithium-ion technologies comprise the vast majority of the market and are generally not well suited to LDES applications. As global commitments to achieve zero-carbon electricity systems accelerate, many countries are evaluating LDES technologies as an alternative to fossil fuel-powered "peaker" plants. Although LDES technologies account for a low fraction of storage deployed to date, it is expected and necessary that installations increase significantly.

The CEC's EPIC program has supported the development of LDES for the past several years, providing a foundation and maturity for potential Utility involvement in FTM demonstration in an operational grid environment. Data collected through the CEC's projects will help inform how LDES assets are operated and what additional benefits they provide beyond short duration energy storage.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	●
Generation	
Transmission	●
Distribution	●
Demand-Side Management	

4. Integration of New Generation Technologies

Innovation Need

Solar photovoltaic (PV) and onshore wind technologies provide mature and well-established methods for renewable electricity generation, but there is a range of emerging and promising generation technologies that will require grid integration and demonstration to better understand their value proposition and potential use cases. While PG&E's EPIC 4 Topic 1, "Microgrid Enablement", proposes to include demonstrations of emerging clean generation technologies as part of microgrid applications specifically, and PG&E's EPIC 4 Topic 3, "Long Duration Energy Storage", proposes to include demonstrations of emerging LDES technologies, there is still a much broader range of emerging generation technologies and potential use cases (e.g. distribution/substation/local transmission capacity, system energy capacity, resilience), that will continue to mature over the coming years and require grid demonstration in the EPIC 4 timeframe.

Description

This topic will conduct grid demonstrations of a range of emerging technologies for electricity generation, to better understand their value proposition and potential use cases and inform pathways for operational deployment. PG&E will not fund the development of the underlying emerging technologies, but rather demonstrate promising candidates as they emerge from the CEC's EPIC program and other applied R&D programs. PG&E will coordinate closely with the CEC as their earlier-stage investments in a range of technologies progress, to identify opportunities to execute partner projects in which the CEC's grants fund the procurement of the new generation systems and PG&E's projects fund PG&E's involvement in integrating these solutions into the grid. Furthermore, technology vendors may be able to access other funding sources such as direct Federal and state grants, and private institutions, and the utilization of EPIC funds will allow such technologies to be interconnected on the grid as a proving ground. Examples of generation technologies to be demonstrated include, but are not limited to, hydrogen, fuel cell, novel geothermal, linear generators, offshore wind, emerging solar PV technologies, and potentially others.

Expected Outcomes

The demonstrations pursued through this topic are expected to result in the following outcomes:

- Grid integration (e.g. engineering design, protection, operations) and demonstration of one or more emerging generation technologies for transmission, substation or distribution use cases
- Validation of combinations of specific technologies and use cases, and development of plans for broader post-EPIC implementation
- Identification of performance requirements to influence future improvements to vendors' product offerings

Metrics and Performance Indicators

- Demonstration of safe and reliable operation of new generation technologies
- Number and total MWh of new generation technology systems successfully installed on the grid and transitioned to steady-state post-EPIC operations
- Availability of standardized market models and integration methods for new generation systems

Primary Users and Beneficiaries

- **Customers** will benefit from the positive environmental impacts of the renewable generation technologies enabled through this topic, as well as potentially reduced bills associated with an overall more cost-effective generation portfolio.
- **IOUs** will benefit from the availability of additional technologies with which to achieve their own and California's climate goals.
- **Regulators and planners** will benefit from knowing the most cost-effective ways of integrating new generation technologies at utility scale.
- **Under-resourced communities** may benefit directly from renewable generation technologies installed and demonstrated within their communities as part of demonstration projects within this topic.
- **Technology developers and manufacturers** will benefit from the learnings of demonstrations which may serve to inform enhancements to their product offerings.

Guiding Principles

- **Safety:** The renewable technologies enabled through this topic may help inform how protection schemes, fuel safety, and other operational considerations need to be established to ensure that they can be operated safely on the grid.
- **Reliability:** The renewable technologies enabled through this topic may help PG&E maintain grid reliability in its transition to 100 percent clean energy.
- **Affordability:** The renewable technologies enabled through this topic may be significantly more cost-effective than current solutions for transitioning to 100 percent clean energy.
- **Environmental Sustainability:** The renewable technologies enabled through this topic will help to reduce the emissions from electricity generation.
- **Equity:** The renewable technologies enabled through this topic may provide viable substitutes for non-renewable forms of generation either located in or directly impacting DACs and other vulnerable communities. Increased renewable and clean energy technology in these communities can have positive impacts on public health by reducing or eliminating pollutants from local fossil fuel power plants and/or local diesel generators. Additionally, EPIC can help support local financial benefits and economic development within DACs by partnering with community-based organizations during demonstrations. Partnerships through EPIC can accelerate local expertise and organizational capacity in an emerging technological area.

Background, Previous Research, and Technology Trends

As mentioned above, solar PV and onshore wind technologies provide mature and well-established methods for renewable electricity generation, but there is a range of emerging generation technologies that are being funded and matured, that will ultimately require grid integration and demonstration to better validate their value proposition, inform potential use cases, and help establish roadmaps to broader grid implementation. The CEC has dedicated an entire strategic objective in their EPIC 4 plan to “Accelerate Advancements in Renewable Generation Technologies”, which will fund the maturation of new solar photovoltaics, offshore wind, and geothermal energy generation technologies. PG&E will monitor the progress of candidate technologies as they emerge from the CEC's EPIC program and other applied R&D programs, in ultimately selecting a subset that are ready for direct utility involvement and grid demonstration to advance the technologies.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	●
Generation	●
Transmission	●
Distribution	●
Demand-Side Management	

Grid Modernization Initiative

Beyond increasing microgrid development, resiliency, flexible zero-carbon generation and storage resources, there must continue to be advancements to the grid itself and its operation in areas such as monitoring, protection, maintenance, and planning. Many types of new sensors and a significantly enhanced communication system are needed to operate the grid safely and reliably through significant ongoing change. Better planning tools are needed to make informed investment decisions around grid architecture over the coming decades in the face of several trends disrupting the current grid architecture. New methods of aerial surveillance, predictive maintenance and more efficient and transparent ways of executing complex work products are needed, and with the rapid increases in the types and location of DERs on the grid, the way that the grid is protected needs to change. This Grid Modernization initiative addresses these needs.

5. Grid Sensing and Communication

Innovation Need

For PG&E to reliably, safely, and efficiently operate the grid of the future, there will need to be deployment of 1) many new sensor types; 2) edge computing to analyze data streams and make autonomous and coordinated control decisions; 3) advanced, pervasive cybersecurity protection; 4) support for far greater data volumes; and 5) a flexible, pervasive, multi-use communication system. There are many new technologies of interest that may address parts of these needs, though many unanswered questions remain about those technologies and how to create a comprehensive whole that addresses all of PG&E's distinct needs together.

Description

This topic will demonstrate new sensing technologies that could significantly advance PG&E's safety, reliability, and affordability goals related to a range of initiatives for wildfire prevention, asset protection, and grid operations. New sensors will generally first be tested in a laboratory setting and then, if successful, installed and demonstrated in a limited number of field sites. Examples of sensors that may be demonstrated include:

- Advanced service meter "grid sensor" including but not limited to sensing compromised neutrals/floating voltages, local grid disturbances, advanced power quality, advanced power flow, grid health, momentary outages, local grid topology, phase detection, and earthquakes.
- Animal/bird strike sensor
- Acoustic camera that can identify leakage currents and degraded components on distribution lines
- Insulator soiling/debris sensor to inform predictive wash schedules, taking into account weather/rain and other factors
- Earthquake detection sensor for reclosers
- Pole and attached equipment health sensors (e.g. inclinometer for tilt, accelerometer for vibration)

- Combined economic packaging of micro weather stations, infrared, acoustic, visual, LiDAR and other sensors, including the other sensors mentioned here
- Long-range high-resolution flame detectors
- Gas sensors and AI to detect smoking/smoldering transformers, capacitor banks, utility poles or other utility equipment
- Additional sensors and use cases that inform predictive analytics to support a proactive asset management model for the distribution system, including investigating the risk-informed prudence of setting end-of-life limits for certain types of grid equipment (e.g., transformers).

This topic will also provide insight into and demonstrate communications options of a highly interconnected utility. Projects will demonstrate technologies needed to create a unified communications platform that includes support for many millions of communicating devices across a wide range of emerging communication media, with a common cybersecurity system, and the resiliency features needed to continue operating while degraded or in times of emergency. The technology demonstrations will also address PG&E's distinct communications challenges related to rugged, remote areas and steep canyons, and need for edge computing to support real time analytics for characterizing the local grid environment and react locally to perturbances. In addition, a prototype modular, upgradeable embedded communication interface for sensors will be developed to enable faster, simpler, secure integration of new sensors into a utility operational network.

In addition, through this topic PG&E intends to demonstrate new high velocity, high density sensor data streams combined with existing sensor data and associated analytics for real-time system protection not possible with current technology.

Lastly, PG&E intends to calibrate existing system models utilizing novel analytics methods and data streams as described herein.

In their EPIC 4 investment plan application, SCE also broadly proposes to explore new grid sensors and edge computing, and both SCE and SDG&E propose to pursue enhancements to their communications systems. These are broad areas of opportunity, and while each utility's projects and the technologies they pursue will be driven by their own distinct priorities and requirements, elements of each utility's efforts will be of applicability and interest to the other utilities. As such, PG&E will coordinate closely with SCE and SDG&E during project scoping to ensure efforts are complementary and not unnecessarily duplicative, and keep them appraised of any relevant results and learnings from its projects.

Expected Outcomes

This topic will provide the following outcomes:

- Demonstration of new sensors that address the various sensing needs as described in this topic, with focus on packaging sensors cost-effectively and re-using sensor data to support multiple use cases
- Demonstration of comprehensive communication systems that support battery-powered edge devices, workforce communication devices, high speed and high data rate producing sensors, leading-edge cybersecurity, coverage across all use cases including use cases unique to PG&E, and support for in-network and edge computing and distributed grid control
- Development of standards and prototypes to enable faster, simpler, more secure, integration of new sensors into a utility operational network
- Development of next generation meter technologies that enable grid edge analytics, earthquake analysis, phase detection, topology analysis, and grid edge area communication and coordination
- Informing PG&E's unified sensor, edge computing, cybersecurity, and communications strategy

Metrics and Performance Indicators

- Number of new sensor types deployed
- Throughput and latency of the communications system for the various and distinct PG&E use cases
- Percent increase of data available for analysis from sensors
- Percent accuracy improvement of information available to analysts

- Percent reduction in enterprise risk from the solutions enabled through this topic

Primary Users and Beneficiaries

- **Customers** will benefit from more efficient and reliable operation of the electric system, with greater ability to support 100 percent clean energy, as well as improved protection from being able to better predict and diagnose equipment issues prior to failure.
- **IOUs** will be able to operate and maintain the grid more efficiently, reliably, and safely.
- **Technology developers and manufacturers** will benefit from demonstrations of their technology, incorporating feedback to improve their products, and subsequent adoption in the utility community.

Guiding Principles

- **Safety:** This topic will not only provide increased safety, but more effective and widespread analysis of electric grid equipment conditions and faster, more effective communications.
- **Reliability:** This topic will not only provide increased reliability, but more effective and widespread analysis of weather and electric grid equipment conditions.
- **Affordability:** This topic offers improvements in affordability by directly preventing costly unplanned outages and damage to utility assets.
- **Environmental Sustainability:** Environmental sustainability is enhanced by the reduction of environmental damage from the prevention of catastrophic grid-related events such as wildfires, and through more efficient and carbon-free operation of the grid resulting in a lower environmental impact.
- **Equity:** Under-resourced communities are often the most vulnerable to and most impacted by outages and extreme weather events. Grid sensing, communication capabilities, and increased visibility into grid assets are important capabilities to prevent outages or mitigate weather-related disasters, potentially avoiding loss of healthcare, education, childcare, and work.

Background, Previous Research, and Technology Trends

IOUs are continuously looking for innovative sensors, communication systems, and analytical methods that can cost-effectively impact operations. National Labs, government agencies, universities, research organizations, and private industry are all developing these technologies that can be employed in the electric sector. However, they are at varying levels of readiness and often lack maturity that comes from demonstration in the harsh and sometimes extreme environment that PG&E operates in and often require specialized maintenance, tuning, and calibration that is not well suited for deployment at scale across large geographic areas. Finally, though PG&E has successfully demonstrated a range of new sensor types, there needs to be improvement in the coordination, management, and ability to synthesize and leverage the value of these and future sensor types.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	**Topic Applicable**
Grid Operations/Market Design	●
Generation	
Transmission	●
Distribution	●
Demand-Side Management	●

6. Grid Scenario Planning

Innovation Need

Existing long-term grid architecture work in progress at PG&E has highlighted four macro trends that are disrupting the traditional architecture of PG&E's grid:

1. Changing environmental and ecological conditions
2. Proliferation of new technologies with declining costs and enhanced capabilities

3. Evolution in how, when, and where end users consume electricity
4. Effective and sustained political will to decarbonize the state of California

The future is uncertain and yet our design principles are often based on what we've seen to date. With these macro trends, there is a need for a long-range whole system grid planning tool to inform decision-making on the 10 to 40-year time horizon. Current tools and processes either plan based upon past behavior and growth, cover only one part of the grid (e.g. generation, transmission, substation, or distribution), do not take into account sufficient up-to-date datasets to inform a comprehensive or accurate model, are too inflexible to answer the questions about the changes needed in the coming decades, or operate too slowly to be of sufficient help in efficient decision-making.

Description

This RD&D topic will support technology demonstration of a grid scenario planning engine to address this innovation need. The aim is to create a whole system grid simulator that analyzes a wide range of scenarios and potential future stressors to the grid, produces a proposed grid model, and distills grid design principles.

The topic would help answer the questions of what the grid should look like in 10 years and out to 40 years. The engine would take future-influencing dimensions as inputs and output what the optimal grid would look like to inform grid design principles and decision-making. These inputs could include usage behavior, major economic stressors, DER integration, EV adoption/building electrification, zonal electrification of the gas system, and climate change. This topic would explore how the model itself would even be built and what recurring datasets would need to be input to keep the model current as the grid topology changes. The model would need to be flexible, provide understandable and actionable outputs such as a grid model, advise on grid design principles, and guide on how to actualize the results. The topic would also explore how such a model's objectives could be configured, for instance, to maximally reduce wildfire risk, maximize energy equity, maximize decarbonization, optimize affordability, or minimize investments.

Included in this topic is the demonstration of the platform that would be needed to operate such a model, as current planning tools have very significant limitations that cannot scale to the enormity of the data (many tens of millions of distributed devices including but not limited to electric vehicles and inverter-based resources) and computations needed to perform whole grid scenario planning in a timely manner. PG&E would also explore whether the platform for this topic could be extended to support the many other short- and long-term studies that are performed, to bring them together out of their silos and to leverage common data and systems to improve the quality and efficiency of the studies and models.

PG&E has been and will continue to work alongside its fellow EPIC Administrators to coordinate on EPIC topics and projects to ensure non-duplication of work, to be able to collaborate on projects when possible, and to share project learnings. PG&E notes that SCE's End-to-end Advanced Simulations and Analytics topic in their EPIC 4 Investment Plan includes elements that may overlap with elements of this PG&E topic. While each utility will need to develop and leverage their own respective models to represent their own distinct systems, PG&E and SCE will continue to work together to ensure that the projects pursued through their respective topics are aligned and avoid unnecessary duplication.

Expected Outcomes

This topic will realize the original vision as proposed for the "Grid of the Future Scenario Engine" project approved, but not pursued, in PG&E's EPIC 3 plan, though with an expanded scope of modeling the whole system (distribution, substation, transmission, supply), with an expanded time horizon of up to 40 years, and with the required computing platform needed to perform such scenario planning, including providing answers to the following example questions:

- How many customers should be connected to a feeder, bank, substation, sub-transmission, or transmission system?
- What voltage levels should we operate at and where?
- How long should our feeders be?
- Where should we underground?

- Where should we conduct zonal electrification of the gas system?
- Where should we install grid-connected microgrids?
- Should the lines even go there?
- Where should we retire lines?
- Where should we re-route around HFTDs?
- Where should we build Remote Grids?
- Where should our lines follow roads vs. where should our lines traverse challenging terrain?

Metrics and Performance Indicators

- Cost-effectiveness of infrastructure investments
- Dollar cost savings of estimated additional avoided stranded assets

Primary Users and Beneficiaries

- **Customers** should benefit from lower rates as infrastructure investment can be more completely optimized and fewer assets might be stranded.
- **Energy regulators and planners**, including at the CPUC and CAISO, will benefit from the analytical approaches and model outputs used to communicate on long-term grid change planning activities.

Guiding Principles

- **Reliability:** The technologies developed under this topic will demonstrate how grid change can be planned out through multiple decades in support of a reliable system for all end users.
- **Affordability:** This topic aims to develop a comprehensive whole system grid scenario planning engine that will support affordability through the avoidance of unnecessary infrastructure investments and reduction of potential stranded assets.
- **Equity:** The modeling and simulation developed through this topic would enable PG&E to explore the best pathways to equitably transform the grid over the coming decades.

- **Environmental Sustainability:** By avoiding unnecessary infrastructure investments and reducing stranded assets there is a reduction of environmental impacts.

Background, Previous Research, and Technology Trends

Some research studies have been performed in this area. The first research, performed by Instituto de Investigación Tecnológica (IIT) Comillas in Spain, has modelled a European-style distribution network with higher secondary voltage and different network topologies than North America's grid. The second research performed by National Renewable Energy Laboratory (NREL) utilizes the findings of IIT Comillas' work and implements it on North American-style grids. Both studies focus on possible future architecture of the distribution network, but not the transmission system or generation. There is also research funded through the U.S. Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E) with purely transmission system focus. However, there is not yet an engine developed to simultaneously model sub-transmission, transmission, and generation parts of the entire grid. The objective of this EPIC topic is to develop a holistic assessment of different possible scenarios of the entire future grid, including customers, primary and secondary distribution lines and components, sub-transmission, transmission, and generation.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	**Topic Applicable**
Grid Operations/Market Design	●
Generation	●
Transmission	●
Distribution	●
Demand-Side Management	

7. *Advanced Drone Applications*

Innovation Need

Currently, PG&E primarily uses manned aircraft and other manned vehicles for grid surveillance of approximately 17,000 miles of electrical transmission, distribution, and management assets. There are safety risks inherent in employing manned vehicles for field-related work, and manual monitoring creates opportunities for human error. PG&E has taken initial steps to incorporate some drone use cases into its operations, including the manual operation of drones within line-of-sight for the routine inspection of high-voltage lattice transmission towers. The continued incorporation of drones through wider and more advanced use cases has significant potential to improve the safety, effectiveness, and efficiency of system operations. Areas of opportunity include routine transmission, substation, distribution, and generation asset inspections, as well as ad hoc investigation of system issues, post-event patrols, vegetation monitoring, and potentially others.

Description

This topic will continue to advance PG&E's drone applications by building upon the initial demonstration of automated and Beyond Visual Line-of-Sight (BVLOS) capabilities currently being demonstrated in PG&E's EPIC 3 program. These capabilities will also be expanded to additional use cases beyond the narrow implementation in EPIC 3 for ad hoc investigation of alerts in the distribution and the automated inspection of lattice transmission towers and involve a wider range of onboard sensors.

Beyond exploring additional use cases, PG&E will also demonstrate better integration between vendor systems and PG&E's own work management systems and processes to enable more efficient workflow execution. PG&E will also explore the progression from limited scope and scale demonstration involving individual drones operating in isolation, to demonstration of smart networks of multiple drones, and explore the more holistic integration of manned and unmanned inspection processes. This topic will also demonstrate the application of larger drones for longer-range operations than have been applied by PG&E to date, which will involve more stringent Federal Aviation Administration (FAA) requirements and require even more robust drone systems.

Expected Outcomes

This topic will position PG&E to operationally deploy advanced drone systems across a range of PG&E use cases. As an expected outcome, PG&E intends to secure FAA approvals to allow for autonomous and BVLOS mission execution to unlock significant efficiency gains across a wide range of use cases, for multiple types and sizes of drones. As an additional outcome, PG&E will also progress from exploration of stand-alone drone systems to integrating vendors' systems into PG&E's own systems and processes. With more robust and advanced drone systems, FAA approvals to allow for broader and more flexible operations, and improved integration between vendor and PG&E systems, unmanned operations will increasingly become a viable and preferred alternative to conventional manned aerial and land-based vehicle operations within PG&E.

The precise, repeatable, and more frequent capture of asset and vegetation data across missions and over time that will be enabled by automated drone operations is also likely to significantly benefit machine learning, to improve asset health assessments, risk modeling work and targeted vegetation work.

Metrics and Performance Indicators

- Reduction in operating costs on an annual or per-operation basis
- Reduction in safety incidents on an annual basis
- Reduction in incomplete or insufficient mission data capture
- Reduction in end-to-end operation process time

Primary Users and Beneficiaries

- **IOUs** will employ and benefit from faster, more efficient, and more effective operations across a broad range of use cases.
- **Customers** will benefit from rate reductions associated with reduced operating costs that result from more efficient utility operations.

- **General Public** will benefit from improved safety due to reduced exposure to hazards associated with conventional manned aerial and land-based vehicle operations.

Guiding Principles

- **Safety:** Drone operations will improve safety by removing exposure to hazards associated with conventional manned aerial and land-based vehicle operations.
- **Reliability:** Drone operations have the potential to allow for faster investigation of emerging grid issues, as well as faster post-event patrols, to prevent outages and lessen the duration of outages.
- **Affordability:** Drone operations have the potential to yield significant operational cost reduction as compared to conventional manned aerial and land-based vehicle operations.
- **Environmental Sustainability:** The use of electric-powered drones will avoid the emissions associated with conventional manned aerial and land-based vehicle operations.
- **Equity:** New applications of drone systems can be deployed in disadvantaged or low-income communities at the wildland-urban interface, to reduce the inequitable wildfire risks faced by those communities, and reduce the inequitable impacts of air quality they face during wildfires

Background, Previous Research, and Technology Trends

The application of drone systems is still nascent within the utility industry. While more utilities are beginning to use drones for various aspects of their operations, most operate them manually and within visual line-of-sight. Few utilities have begun to employ automated, remote, and BVLOS drone applications, and in these cases, most operate within a limited range of use cases and narrowly-defined operational parameters. However, as both vendor solution offerings advance, and FAA regulation becomes more accommodating of advanced applications, there is increasing potential for PG&E to demonstrate and integrate advanced drone applications for the benefit of its operations and customers. Specifically, PG&E's EPIC 3.41 - *Drone Enablement and Operational Use* project is currently conducting a limited foray into demonstrating automated and BVLOS drone operations for very targeted use cases and operational parameters. PG&E intends to continue to work with drone system vendors and the FAA to advance its capabilities within EPIC 4.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	**Topic Applicable**
Grid Operations/Market Design	
Generation	●
Transmission	●
Distribution	●
Demand-Side Management	

8. Advanced Predictive Maintenance and Failure Cause Analysis

Innovation Need

In recent years, PG&E has begun to move to a more predictive and proactive mode of managing certain types of its assets. This change has involved improvements in inspection practices, as well as more data-driven monitoring that has involved both the deployment of additional sensor devices in the field and the development of purely analytical capabilities leveraging the extensive data PG&E already has at its disposal. Analytical capabilities have significant potential to provide actionable insights in managing assets and mitigating risks.

While administering its EPIC program, PG&E has built up a strong team of data scientists that have gained significant experience and expertise around grid and utility operations. In addition, PG&E is undergoing a major effort to improve data quality and access by establishing its central Foundry data management platform. These factors have contributed to the recent successful deployments of predictive maintenance tools, such as the tool developed through PG&E's EPIC 3.20 - *Data Analytics for Predictive Maintenance* project, for identifying issues with distribution transformers. However, there is an opportunity and need to continue developing analytical tools for the distribution system, where PG&E has been most focused to date, as well as for the transmission system and substations where there are perhaps even richer datasets and significant opportunity to develop powerful tools. Purely analytical tools have the potential to yield more cost-effective risk mitigation (or "risk-spend efficiency") as compared to other solutions that require the broad deployment of sensors and other hardware across the system.

Description

This topic will apply analytics to improve management and operation of assets and asset data for a range of asset types across distribution, transmission, and substation, as well as develop tools to predict deterioration, imminent failures, remaining useful life, high risk conditions, and the need for maintenance across these asset types. In line with these objectives, the models that are developed will also help to more accurately categorize asset failure mechanisms, improve data quality, and shed light on conditions in the system such as energy theft and unauthorized interconnections.

The overarching opportunity associated with this topic is to continue to derive as much value as possible out of the expansive set of data PG&E has at its disposal. Data sources applied to this topic will include, but not be limited to, SmartMeters, outage records, geographical information systems (GIS), weather data, supervisory control and data acquisition (SCADA), and other operational data sources. While building and demonstrating new analytical tools, it is expected that additional foundational work will need to be done to improve the quality, structure and accessibility of various underlying data elements. PG&E will also conduct extensive postmortem analysis of failed assets to better understand root causes of failures and inform the development of the predictive models.

The tools developed through this topic are expected to be applied in a decision horizon between days and months, which places them between the strategic planning timeframe and the real-time operational timeframe. For the distribution system, assets of potential focus include capacitors, reclosers, regulators, and underground conductors. For substations, the initial focus is likely to be on transformers and circuit breakers, before expanding to other assets. Assets of focus for the transmission system will include support structures (e.g., poles, towers, foundations), cross-arms, conductors, overhead ground wires, splices, jumper cables, anchors and guy wires, insulators, and various connector components.

Expected Outcomes

The demonstration projects conducted through this topic will result in predictive tools, connected to real-time operational data feeds, that are ready to transition into production development and use. Ongoing maintenance, and operational work processes and associated roles and responsibilities will be established for monitoring and triage of tool outputs, continuous improvement of the tools, as well as field investigation and corrective action. The following are additional expected outcomes:

- Significant intellectual property in the user interfaces and core algorithms developed, which PG&E will aim to apply to the maximum benefit of the EPIC program's customers. This may involve patenting, licensing, and monetization
- Improvements to the quality, structure and accessibility of the various underlying data elements that will be inputs to the tools that are developed
- Enhancements to PG&E's own internal data science expertise
- Enhancements to PG&E's central Foundry data platform

Metrics and Performance Indicators

- Number of asset types for which successful predictive models are developed
- Number and percent of true and false positive and negatives generated by the predictive models
- Number and percent of true positives predicted by the tools that were not otherwise identifiable by existing means
- Risk-Spend Efficiency estimates of tools if deployed at scale

Primary Users and Beneficiaries

- **IOUs** will leverage the tools developed through this topic for improved asset management of their own service areas.

- **Technology developers** may integrate the models developed through this topic into their own product offerings through licensing agreements with PG&E and make these capabilities available to a broader set of utilities outside of California.
- **Customers** will directly benefit from the reduction of risk and mitigation of outages that result from the tools developed through this topic. They may also benefit from any monetization by PG&E of the intellectual property developed, through a reduction in rates.

Guiding Principles

- **Safety:** Predictive maintenance tools prevent asset failures that could pose safety risks to utility employees and the general public. Preventing asset failures also reduces ignition risk.
- **Reliability:** Predictive maintenance tools prevent asset failures that cause outages for customers.
- **Affordability:** Predictive maintenance tools prevent failures and allow for preventative maintenance as opposed to more expensive unplanned asset repair and replacement, which reduces utility operating costs. Predictive maintenance models are also broadly applicable to other utilities, and there is an opportunity to license and monetize intellectual property and return a portion of the funds to customers.
- **Environmental Sustainability:** Predictive maintenance tools prevent asset failures that could ignite wildfires.
- **Equity:** Under-resourced communities are often the most vulnerable to and most impacted by outages and extreme weather events. Understanding past failure causes and proactively predicting maintenance of grid assets are important capabilities to prevent outages or mitigate weather-related disasters, avoiding potential loss of healthcare, education, childcare, and work.

Background, Previous Research, and Technology Trends

PG&E’s EPIC 3 predictive maintenance projects made great strides in the state of the art but were limited in scope and performance by some challenges in data quality and availability. In general, the state of the art in predictive maintenance within the energy industry continues to improve though has consistently been limited by data quality challenges. PG&E will leverage its broader investments in data quality and process improvements, while leveraging the learnings of National Labs, utilities, and others to continue to push the state of the art forward. The existing frameworks for predictive maintenance and asset failure analytics will provide a path to production for any viable solutions developed.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	
Generation	
Transmission	●
Distribution	●
Demand-Side Management	

9. Work Management

Innovation Need

Many PG&E processes, and particularly complex processes and those that involve multiple stakeholder groups, can include multiple manual tasks, be inefficient, or have limited or outdated underlying technology solutions to operate them. With the advent of a multitude of new data sources related to these processes and PG&E's Foundry-based data integration and analytics platform that can leverage them, new analytical models could supplement or be a significant part of replacing them. These new tools would improve field employee situational awareness, project/worker safety, efficiency, and an improved customer experience.

Description

This topic would enable the demonstration of a range of technologies that could help improve various PG&E work processes, such as:

- Analytical models to optimize resource allocation and work staging. Examples of opportunities include:
    - Work management tool for wildfire risk areas. Every day, prior to work starting on a job, there are a myriad of mitigations that need to be taken based on location, weather, High Fire Threat District (HFTD) tier, and other operational and fire science-related data. This time-consuming mitigation calculation is performed manually and may be subject to error and interpretation. A tool that would replace this process would ideally be installed on the field workforce equipment and be able to automatically provide the needed mitigations quickly using the needed disparate sets of information sources.
    - Fully automated emergency field site construction tool. In order to release an emergency field site (e.g., a Base Camp, Micro Site, Staging Area, Materials Laydown Yard, or Landing Zone) to Construction, there is complex information exchange and decision making by numerous internal and external stakeholders. The tool would employ novel data and coordination processes and result in faster and more efficient time to completion of emergency site approval, equipment mobilization, vendor services, and buildout thus increasing safety and lowering costs.
    - Field employee situational awareness tool to make the field worker aware of all relevant customer-, service-, and location-related information. Such a tool would use machine-learning techniques to determine the relevant information from the disparate data sources and provide an organized report suitable for rapid consumption by the field worker. The benefits are manifold, including improved customer service, safety, efficiency, and lower environmental impacts of field work.

- Augmented reality tool for shared situational awareness in standard and emergency conditions. One use case would be for providing a remote analyst with the ability to see the field worker's point of view in both standard operational and emergency conditions, to most quickly develop the most effective and safe plan of action. Another use case would be for remote operators or engineering SMEs to be able to provide overlaid diagrams and guide field technicians through a complicated procedure or repair, for enhanced safety and quality. This will also reduce the costs from, and interruption caused by, return jobs needed for re-work.
- Restoration time optimization tools that analyze the affected grid area for its topology and equipment, dynamic power flows, BTM DERs in the area, power factor, crew and resource availability, including prior work by SCE and SDG&E as referenced below.

PG&E notes that SCE's Safety and Work Methods Advancement topic in their EPIC 4 Investment Plan includes elements that, at a high level, overlap with elements of this topic. Work methods and work management is a broad area, and PG&E and SCE will continue to work together to ensure that projects that may be defined through their respective topics are aligned and avoid unnecessary duplication.

Expected Outcomes

- New work management tools that reduce risk, increase safety, improve efficiency and coordination, and reduce costs

Metrics and Performance Indicators

- Number of hours of employee time saved from the implementation of work management tools developed through this topic
- Number of hours of reduction in time to release emergency field sites to the construction group
- Number of hours saved in restoration time as a result of optimization tools developed through this topic

Primary Users and Beneficiaries

- **Customers** would benefit from an increase in safety as well as greater affordability through reduced utility costs.
- **IOUs** would benefit from more efficient, less error prone, safer work processes.

Guiding Principles

- **Safety:** Improved processes built on more complete data, and less prone to errors and interpretation, would lead to an increase in safety.
- **Reliability:** Improved efficiency of work would enable more scheduled work to be performed sooner, enhancing reliability.
- **Affordability:** Improvement to work management would result in lowered costs and greater affordability.
- **Environmental Sustainability:** More efficient work processes would lead to a reduction in environmental impact and a reduction in emissions from operations.

Background, Previous Research, and Technology Trends

PG&E's EPIC portfolio to date has not focused extensively on work management. Now that PG&E has established foundational data, analytics, and mobile workforce capabilities, PG&E can now leverage them to demonstrate the work management capabilities described in this topic. Regarding augmented reality, PG&E has observed the advancement of utility-specific augmented reality solutions, including through the EPRI Incubatenergy Labs program, which has explored application of augmented reality systems. PG&E is also aware of the augmented reality program SCE created to improve the way that linemen diagnose complex automation and protection equipment, determine if equipment is energized, and make repairs. PG&E is also aware that SDG&E, in its EPIC-3 Project 4, "Safety Training Simulators with Augmented Visualization", demonstrated and evaluated augmented reality applications for field-focused design, operations, and asset monitoring and management solutions in utility power systems, with a focused patrol simulator for the benefit of operator trainees, and a safety procedure aid for underground distribution field work. PG&E's emergency operations-focused use case for augmented reality is distinct from the SCE and SDG&E use cases. In general, augmented reality solutions for utilities are at an early stage and quite limited in capabilities. Technology options and innovative solution offerings are increasingly presenting an opportunity to make advancement through demonstrations in this area.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	●
Generation	
Transmission	●
Distribution	●
Demand-Side Management	

10. System Protection

Innovation Need

PG&E's electric system is changing rapidly, including from the significant increases in BTM and FTM DERs and renewable energy-based microgrids. PG&E's commitment to reliable, safe energy supply for its customers cannot be compromised, though the characteristics of these DERs and microgrids challenge our System Protection equipment, standards, and strategies. Many unanswered questions remain in how to maintain and improve system protection as the grid equipment changes. There is also a need to further reduce wildfire risk from equipment ignitions and other environmental risks through innovations in system protection.

Description

This topic will demonstrate technologies needed for improved system protection in several areas:

- Improvement of system protection systems for faults generated by inverter-based resources including battery energy storage systems, as present protection systems rely on a current profile that is not provided in inverter-based microgrids. The current protection systems in these cases would not be fast enough to prevent an ignition. The demonstrations will focus on characterizing the faults common to inverter-based resources and microgrids, including fault types that are difficult to detect by existing protective relays, including by not limited to high impedance faults. The work would begin with inverter-based resource fault modeling seeking improvements to the modeling, validation of the models through laboratory testing, then application of the lessons learned and verification of the models and protection schemes through field installations.
- In companion with the above, demonstration of a new type of protective relay that uses “traveling waves” to detect faults instead of the traditional “phasor-based element” method. Traveling wave fault detection relays do not rely on elevated current levels and instead detect “disturbances”. This would detect faults from batteries and inverter-based resources. Traveling wave relays could also be used to reduce wildfire risk since they can detect faults before they create damage (like broken conductors).
- New equipment that can add the needed modern telemetry (e.g. three phase reactive power) to legacy electro-mechanical substation relays without costly and service-disruptive relay replacements.
- Novel protection schemes that use machine learning applied to advanced line reclosers to detect more types of faults and to detect faults more quickly.
- Characterization of the effects on the primary neutral from three-phase opens during EPSS events.
- Novel capacitor bank controllers with precision three-phase multi-parameter telemetry are needed for the ADMS system, as well as for emerging improved substation and feeder protection analytics, for instance when combined with new substation-based telemetry as described above, the system could detect incorrect capacitor switching schedules, and partial capacitor fuse or switch failures. This analysis and protection can

prevent ignitions due to capacitor failures and can improve the power quality performance of the grid.

- Adaption of transmission-level system protection algorithms to distribution system relays, in particular distance protection that analyzes voltage, frequency, current, and time all at once and applies various trip zones. Implementing distance protection in the distribution system would enable greater precision in limiting tripping to only directly impacted areas. This is particularly needed as the broad deployment of EPSS has limited fault currents and drastically limited time current coordination, therefore distance protection could allow for better coordination between protective devices. Differential protection is another transmission level protection algorithm that would allow better coordination and faster tripping in distribution. There are significant unsolved challenges that presently prevent the use of distance protection in distribution systems. This topic would investigate and demonstrate potential solutions to such issues, such as: enabling full load or generation output with the distance element settings when there are varying conductor sizes and presence of laterals; difficulty in detecting high impedance faults; coordination with Time Over Current (TOC) devices; and solutions for ground protection as it is not feasible to create ground distance protection on certain distribution installations due to wood pole construction, variable circuit topography, and grounding methods.
- New smart fuses that include telemetry to help improve EPSS operation.
- New fuses that would enable the removal of fuses that currently contain powerful greenhouse gases.
- Use of SmartMeter edge disturbance detection for fault isolation and system protection improvements.
- In coordination with PG&E’s EPIC 4 Topic 5, “Grid Sensing and Communication”, application of various communications technologies to improve tripping times and separating the electrical systems that cannot detect faults on their own.
- In coordination with PG&E’s EPIC 4 Topic 18, “Pinpointing Fault Location”, installation of fault location sensors and development of automatic fault location tools to determine

the location of faults quickly and accurately. This will enhance the restoration time and improve reliability.

PG&E has been and will continue to work alongside EPIC Administrators CEC, SCE, and SDG&E to coordinate on EPIC topics and projects to ensure non-duplication of work, to be able to collaborate through joint projects when possible, and to share project learnings. PG&E notes that SCE's Adaptive Protection topic in their EPIC 4 Investment Plan includes elements that may overlap with elements of this topic. PG&E acknowledges that this is a broad area, and that PG&E and SCE will continue to work together to ensure that projects that may be pursued through their respective topics are aligned and avoid unnecessary duplication.

Expected Outcomes

The expected outcomes from this topic include:

- Demonstrations of new analytics, techniques, and equipment targeted at maintaining and improving system protection in the face of significant grid changes
- Informing the strategy for how these new system protection equipment, techniques, and systems could be added to, or perhaps replace, elements of existing system protection schemes
- Standardized approach to protections for microgrids formed utilizing inverter-based resources where fault current may be insufficient for conventional over current schemes

Metrics and Performance Indicators

- Number of nuisance faults prevented
- Number of reportable system protection-related events avoided
- Number of grid equipment failures prevented
- Amount of additional wildfire risk reduction as a result of protecting equipment that otherwise could have started a wildfire when faulting
- Amount of interconnection process time avoided for inverter-based resources specifically due to faster system protection analysis enabled from this work

- Improvement in System Average Interruption Duration Index (SAIDI) and Customer Average Interruption Duration Index (CAIDI)

Primary Users and Beneficiaries

- **Customers** will benefit from an improved protection system that better protects customer equipment and reduces wildfire risk with a minimal number of false fault detections.
- **IOUs** will benefit by maintaining or increasing reliability and protection capabilities as the grid transitions to high inverter-based resources.
- **Grid operators** will benefit from a more reliable and safe system that more clearly identifies faults and fault sources, including the types of faults from new types of resources that conventional protection systems weren't designed for.
- **Technology developers and manufacturers** will benefit from the feedback on product design and operation through the demonstrations, as well as input on potential new types of equipment, sensors, and monitors that would in the future provide higher levels of system protection.

Guiding Principles

- **Safety:** A primary benefit of the topic is increased safety by properly detecting and acting on faults of all kinds, including the new types of fault conditions not readily detectable by traditional protection equipment. This increased protection can also reduce wildfire risk.
- **Reliability:** Reliability will increase when faults and power quality issues are correctly identified and dealt with more quickly and precisely.
- **Affordability:** As faults and wildfires cause expensive damage and destruction, a grid that better protects itself and customers' equipment from these events is more affordable.
- **Environmental Sustainability:** There is a benefit to the environment from prevention of wildfires, reduction of grid equipment that is damaged and requires replacement, and potentially a reduction of use of a potent greenhouse gas.

- **Equity:** As many vulnerable, under-resourced communities are in high fire threat areas, they would benefit from additional wildfire risk reduction.

Background, Previous Research, and Technology Trends

System protection is the cornerstone of safe and reliable operation of the electric grid, and consequently has steadily become more complete, but the introduction of inverter-based resources has complicated protection schemes and subtly slowed the connection processes for microgrids, as each installation became a custom protection scheme.

Inverter-based resources have also made detecting faults more challenging since present protection practices are based on equipment that relies on traditional generation sources. Traveling-wave and incremental-quantity-based relays are state-of-the-art technologies that do not possess these limitations, therefore helping to potentially overcome some of the new challenges associated with microgrid protection.

With the advancement of sensor and control systems, a more sophisticated approach to system protection can be enacted. System protection can be smarter and more localized with faster response and even become learning-based.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	**Topic Applicable**
Grid Operations/Market Design	●
Generation	
Transmission	●
Distribution	●
Demand-Side Management	

CHAPTER 3: Increase the Value Proposition of Distributed Energy Resources to Customers and the Grid

Distributed energy resources (DERs) are key to achieving California's clean energy goals. DERs have the potential to deliver significant benefits to grid operators and electricity users in a high-renewable, highly electrified future. These potential benefits include load flexibility, peak demand reductions, reducing or deferring grid upgrades and associated costs, and improving climate resiliency, grid reliability, and providing compensation to DER owners. There are, however, operational challenges to integrating and maximizing the value of DERs on the grid. The topics in this strategic objective are grouped into the Distributed Energy Resources and Load Flexibility initiative, and the Transportation Electrification initiative. The topics will help develop the technologies and operational capabilities that will improve our understanding of how to maximize the value proposition of distributed energy resources to customers and the grid.

Distributed Energy Resource Integration and Load Flexibility Initiative

The ability to integrate an increasing number of DERs into the grid, and the ability to understand, direct, optimize, and compensate for power flows on a high renewables grid is central to meeting the State's clean energy goals. The following topics will help PG&E achieve these goals.

11. Interconnection Enablement

Innovation Need

Large, localized loads and generation, when not synchronized, can cause reliability challenges. In the face of accelerating load growth from building and transportation electrification, PG&E has limited available distribution service capacity, long lead times for, or external impediments to, building new capacity, and limited capital available for capacity investments. As a result, PG&E is often either unable to interconnect new customer loads or generation or must set static constraints on their operation for them to be interconnected. Rapidly increasing EV charging loads, including from commercial EV fleets, would require significant grid infrastructure upgrades at a rate that would not be possible to accommodate using only currently available solutions for accommodating new service connections. Similarly, PG&E has limited hosting capacity for new generation. New generation resources often face costly and long lead time capacity upgrades that may be able to be mitigated with novel and advanced solutions. In short, there is an urgent need and opportunity to explore a wider range of solutions for eliminating barriers to timely, smarter, more flexible customer service connection and generation interconnection.

Description

This topic will demonstrate a range of solutions for enabling the interconnection of distributed energy resources and new service connections of new and growing residential and commercial customers' loads and DERs, beyond conventional upgrades to conductors and transformers or the establishment of static constraints as a prerequisite for interconnection.

This topic will explore the enhancement of PG&E's Distributed Energy Resource Management System (DERMS) capabilities to provide greater visibility into dynamic grid capacity and convey signals or commands to participating DERs as an alternative to static constraints. This could allow for all customers to be treated as flexible load and/or generation, and not just the customers that would have otherwise triggered the need for upgrades. Enabling technologies at the meter or on the customer side such as smart inverters, smart panels, load control devices, load limiters and smart appliances could be included in the demonstrations. The demonstration of dynamic load and generation management will potentially also inform updates to standards and the implementation of new customer programs and interconnection offerings.

This topic may also further explore the establishment of dispatchable storage, (either front-of-the-meter (FTM) or behind-the-meter (BTM), as a short or long-term alternative to distribution upgrades. One potential use case for demonstration would be to partner with an EV charging infrastructure vendor on the use of stationary or portable battery storage to avoid a spike in grid demand at a small to medium size charging site. Other areas of exploration include the use of price signals or peer-to-peer transactional markets to relieve capacity constraints on the distribution system.

Lastly, this topic will also explore streamlined approaches for ensuring cybersecurity of new DERs and other dynamic load management equipment that are interconnected to the grid. For example, this topic may demonstrate the use of blockchain technology as a more distributed and cyber-secure approach to integration with 3rd party-owned equipment.

Expected Outcomes

The following are the expected outcomes of the demonstrations conducted through this topic:

- Faster and less expensive connection of customer loads and DERs
- Demonstration of dispatchable FTM storage as an alternative or bridge to conventional upgrades at one or more sites
- Enhancements to PG&E's DERMS platform to allow for communication of dynamic constraints to customers' DERs and dynamic load management equipment to enable automated load management
- Updates to standards and the implementation of new customer programs for participation in automated load management and flexible interconnection
- Implementation of new solutions that provide greater visibility into dynamic grid capacity
- Evaluation of local control technologies and requirements to respond to grid signals
- Advisory plan for cybersecurity implementation of the DERs and dynamic load management equipment

Metrics and Performance Indicators

- Reduction in time to connect new load and generation on capacity-constrained feeders
- Number of customers participating in flexible service connection and flexible interconnection arrangements through alternate solutions, that would have otherwise required conventional system upgrades
- Avoided costs associated with alternate interconnection solutions

- Increased capacity utilization of grid (rather than planning and building for worst case scenario)
- Faster, more flexible and potentially more cost-effective service connection and generation interconnection processes
- Deferred or avoided system upgrades driven by service requests (i.e. electrification) and new generation interconnection requests

Primary Users and Beneficiaries

- **Customers** will benefit from decreased costs and timelines for the interconnection of their DERs
- **IOUs** will benefit from reduced operating costs and improved customer satisfaction from less costly and faster DER interconnection processes
- **Under-resourced communities** will benefit from reduced barriers to access to clean DERs within their communities
- **Technology developers and manufacturers** will benefit from learnings gained through technology demonstrations that will help them enhance their product offerings

Guiding Principles

- **Safety:** Visibility into dynamic grid loading can avoid safety hazards in hometowns caused by overloaded equipment.
- **Affordability:** The alternatives to conventional distribution transformer and conductor upgrades demonstrated in this project will not only reduce interconnection timelines but will also likely reduce total costs.
- **Environmental Sustainability:** Removing barriers to interconnection enables the proliferation of clean DERs on the grid.

Equity: While the solutions demonstrated through this topic will be broadly applicable to all customers, PG&E will explore opportunities to conduct demonstrations in Disadvantaged and Low-Income Communities specifically, to reduce costs and barriers to clean DER integration in those communities.

Background, Previous Research, and Technology Trends

While exploration of procuring DERs to defer planned capacity upgrades as “non wires alternatives” has been underway in California and elsewhere, the use of DER controls to manage operational (i.e. real-time) distribution grid capacity constraints is still in its infancy with limited RD&D projects having been executed across the country to explore the topic. This effort would build upon past industry and PG&E work in this area including PG&E’s EPIC 2.02 - *Distributed Energy Resource Management System* and EPIC 3.03 - *Distributed Energy Resource Management System (DERMS) and Advanced Distribution Management System (ADMS) Advanced Functionality* projects, to further develop and validate the key technologies, integrations and processes required to operationalize these critical use cases at scale. This topic will also leverage previous efforts to develop grid responsive load and generation controllers that can reliably respond to utility signals and commands. Additionally, the topic will continue to facilitate further development of key standards for DER capabilities and communications protocols that continue to evolve and mature as the industry strives toward more plug-and-play integration across the DER ecosystem.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	●
Generation	●
Transmission	
Distribution	●

Demand-Side Management	●

12. *Advanced Distribution Power Flow Management*

Innovation Need

As DERs along with transportation and building electrification loads continue to grow, power flow on the distribution system and secondary side of service transformers is increasingly complex. There is an urgent need for accurate and timely visibility into power flow, that, among other things, will be used to maximize the value of DERs for customers and for the utility. There is also a need for deeper and wider coordination, optimization, and facilitation of compensation to the DER owners for cooperating to provide grid services.

Several constraints additionally drive the need for this innovation. They include limited distribution service and substation capacity, many limitations impeding complete distribution or substation upgrades, and that if an upgrade is required it may take longer to complete the upgrade than is required to keep up with the DER supply and electrification growth needs.

Description

This topic will demonstrate a range of capabilities to meet the innovation need:

- Correctly inferring the topology of the grid with higher fidelity through new analytical methods that combine with existing SmartMeter data, SCADA, GIS, other available and novel grid sensors, next generation meters, and other data sets. This builds upon prior work through EPIC 2.14 - *Automatically Map Phasing Information*, and subsequent analytical work; the result will be an accurate and up-to-date topology that will be used to first identify transformers mapped in the wrong location, laterals in abnormal switching states, un-documented jumpers, and other errors. This first will be used to improve the safety, efficiency, and reliability of the grid. Secondly, the results will be used as the accurate foundation that other parts of this topic will build upon to maximize the value of DERs.

- Accurate visibility of power flows in the distribution system, on secondaries, and in microgrids through a combination of existing telemetry-enabled grid equipment, grid sensors, SCADA, as well as new sensors. The visibility tool would also be able to identify instances of PV overgeneration and unpermitted PV generation to inform safety-oriented operational practices. The tool would also provide worker safety benefits through real-time notification of unexpected power flows in the area where workers are known to be operating.
- Automated tool that can identify grid constraints, overloaded equipment, and reverse power flows.
- Expansion of the foundational DERMS work performed through PG&E's EPIC 3.03 - *Distributed Energy Resource Management System (DERMS) and Advanced Distribution Management System (ADMS) Advanced Functionality* project, to progress from DER communication to DER control.
- Operational flexibility capability is the ability of a grid operator to make grid topology changes as operational conditions change, such as for maintenance, upgrades, equipment failures, or for emergency situations. DERs pose an additional worker safety, protection, and management challenge as grid topology changes are made. Additional DER-related operational flexibility capabilities need to be developed, demonstrated, and operationalized.
- An automated tool to identify areas where grid upgrades could be deferred if customers in the area added sufficient amounts of grid-supporting EVs, energy storage, PV, and load control devices. An analysis of customer behavior to determine viability would be included in this tool project.
- Building upon the foundational work of EPIC 2.03 - *Smart Inverters* and low-cost telemetry aspects of the EPIC 3.11 - *Distributed Energy Resource Management System (DERMS) and Advanced Distribution Management System (ADMS) Advanced Functionality* projects, PG&E continued validation of the advanced features of IEEE 2030.5 Smart Energy Profile Application Protocol including, for instance, dispatching and curtailing. This validation would include testing with many different smart inverters in a

high DER environment, to assess the amount of BTM DER curtailment that is occurring to determine what could be changed to reduce the amount of BTM DER curtailment or other undesirable interaction between the smart inverters. Included in this work would be a demonstration of the emergent use cases from the Smart Inverter Operationalization Working Group (SIOWG).

- Capabilities to load share during overload situations by novel technologies that can direct power flows from an underutilized grid area to the overloaded grid area.
- Automated operational tool that would coordinate and optimize dispatching of all available FTM DERs as well as BTM DERs including EVs and flexible loads. Additionally, the tool would provide hourly and day ahead distribution forecasts for a feeder. This topic would also inform PG&E on how such a tool would progress toward operationalization in a Distribution System Operator (DSO) model.
- Development and demonstration of uses cases for DER export (including grid support and market participation), along with corresponding communication and control schemes as well as customer preference and compensation including micro-payment models. Use cases include normal operational conditions, under operational flexibility grid topology changes, and in emergency and overload situations.

Expected Outcomes

The expected outcomes from this topic include:

- An accurate, highly-detailed grid topology tool
- Accurate, real-time power flow visibility
- Expansion of DERMS to include DER control
- Accommodation for operational flexibility needs
- Automated tool that determines grid upgrade deferral opportunities
- Deeper understanding of smart inverter capabilities, integration, curtailment, and high-DER inverter interactions
- Grid-supportive DER optimization tool with a customer compensation demonstration

- Wildfire risk reduction due to additional protection from equipment overloads, degradation, and damage as well as identification of switching or configuration errors that could cause ignitions

Metrics and Performance Indicators

- Accuracy of topology analysis created versus actual
- Ability to detect switching or configuration errors
- Accuracy of distribution power flow measurements versus actual
- Ability to identify grid constraints, overloaded equipment, and reverse power flows
- Ability to provide hourly and day ahead distribution forecasts for a feeder
- Ability to compensate DER owners for providing grid support
- Number of DER owners that participate in and receive compensation from the demonstrations

Primary Users and Beneficiaries

- **Customers** will benefit from the reliability, safety, affordability, and environmental sustainability improvements realizable through this topic, as well as from potential compensation for grid support.
- **IOUs** will benefit from grid support of participating DERs as well as the ability to meet DER and electrification load growth without capital-intensive grid capacity upgrade projects.
- **Grid operators** will benefit from new tools that improve the reliability and safety of the grid.
- **Technology developers and manufacturers** will benefit from having their emerging products evaluated and demonstrated and would be able to improve their products through demonstration experience and utility feedback.

Guiding Principles

- **Safety:** Power flow visibility enables additional grid protection that can prevent ignitions as well as improve worker safety.

- **Reliability:** A grid that is protected from power flows that are beyond operational limits will be more reliable. Enhanced reliability will also come from optimizing the participation of all FTM and BTM DERs as well as load management in support of grid stability.
- **Affordability:** Being able to defer capital intensive grid upgrades through optimization of FTM and BTM resources will lead to greater affordability. Affordability is also enhanced through compensation to DER owners for participation in grid support.
- **Environmental Sustainability:** Sustainability is served by increasing the amount of renewable energy that can be integrated into grid operations.

Background, Previous Research, and Technology Trends

The National Renewable Energy Laboratory (NREL) has recently developed a real-time optimal power flow-based distribution resource management system. The capabilities include the management of a distribution system with a high penetration of DERs including by leveraging the data from advanced metering devices and building management systems. NREL has used grid emulators to test the platform, though as the platform has not yet been tested in a realistic grid-installed scenario or even with actual grid models and data, its real-world applicability and behavior is unproven. A more advanced platform could be developed and tested properly in a real-world grid environment through this topic. This topic area would also build upon the DER head-end communication and control system developed with EPIC 3.03 - *Distributed Energy Resource Management System (DERMS) and Advanced Distribution Management System (ADMS) Advanced Functionality* project. That project enabled low-cost sharing of DER telemetry data, and PG&E will now leverage this platform to build out the control side allowing for communication of dynamic constraints to customers' DERs and dynamic load management equipment to enable automated load management capability.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	●
Generation	
Transmission	
Distribution	●
Demand-Side Management	●

Transportation Electrification Initiative

As California pursues ambitious targets to transition the transportation sector to zero-emission technologies, PG&E needs to improve its ability to support reliable, compatible, affordable, coordinated charging solutions located where and when needed. PG&E has also committed to deploying an unprecedented amount of electric vehicle second-life battery energy storage in a short number of years. The two topics in this Transportation Electrification initiative support these targets and commitments.

PG&E recognizes no duplicative or conflicting activities between D. 22-08-024[20] and D. 22-11-040[21] and the topics described below that comprise this Transportation Electrification (TE) initiative . PG&E will pursue opportunities to share EPIC project outcomes and learnings with teams working on activities related to these two decisions as the outcomes and learnings from EPIC may ultimately serve to be complementary to the objectives and directives in D. 22-08-024 and D. 22-11-040. With regard to D. 22-08-024, the objectives and areas of study within the TE EPIC projects do not seek to develop protocols that would either conflict with or change the applicability of the protocols established in D. 22-08-024. While the EV infrastructure rebate programs established in D. 22-11-040 have not yet been designed and implemented, PG&E

[20] D. 22-08-024 Decision Adopting Plug-In EV Submetering Protocol and EVSE Communication Protocols

[21] D. 22-11-040 Decision On Transportation Electrification Policy And Investment

does not anticipate overlapping or conflicting activities with the TE EPIC projects as they will not seek to design and implement new EV infrastructure rebate programs.

13. Electric Vehicle Charging and Integration Enablement

Innovation Need

Electric Vehicles (EV), from fleets of medium and heavy trucks to millions of light duty vehicles, rely on reliable, compatible, affordable, coordinated charging solutions located where and when needed. Substantial innovation, demonstration, and coordination will be required to scale EV adoption in support of California's climate sustainability goals. Through this topic, PG&E will leverage prior CEC research and work cooperatively with stakeholders to understand and address the challenges that an evolving EV charging and integration landscape presents to the grid.

Description

PG&E will conduct demonstrations in the following areas:

- Improvement of the EV charging experience for all customer segments and charging profiles. This includes exploration and demonstration of:
  - Bidirectional fast DC and AC charging systems
  - Fixed or in-motion wireless charging technology
  - Novel battery swapping systems
  - Powering EV charging locations though movable energy storage solutions
  - EV submetering systems and equipment
- Incentivized and managed charging of EVs to minimize grid congestion and align with availability of renewable resources.
- Interoperability and coordination of customers to use vehicle-to-anything (V2X) integration for customer resiliency for planned and unplanned grid outages, in support of the electric grid, or for other potentially beneficial use cases. This demonstration would include creation of an EV charging and V2X technology laboratory for the

purposes of this topic as well as for the purpose of being an available industry resource to test interoperability and help speed the advancement of EV technology.

- Analysis to understand of the round-trip efficiency of EV charging and V2X to inform grid planning.
- New and novel EV detection methods to:
    - Enable the Advanced Distribution Management System (ADMS) and Distributed Energy Resources Management System (DERMS) to coordinate behind-the-meter (BTM) resources, balance load and supply, and potentially avoid or defer grid upgrades
    - Better predict transformer overload and prevent service interruptions and ignition risk
    - More effectively target customers for EV related programs or to encourage off-peak charging
- Analysis of electrified PG&E service vehicles as mobile, plug-in power facilities in times of emergency or for critical loads during grid outages or in times of grid constraints.
- Exploration of effective pathways to best support vulnerable, underserved, disadvantaged and low-income communities with appropriate EV charging solutions.
- Exploring the integration of EV and Electric Vehicle Service Equipment (EVSE) submeter data with PG&E Advanced Metering Infrastructure (AMI) data, including:
    - Potential to transmit smart meter data over EVSE wireless connections in real-time
    - Analysis of submetering data and EV and EVSE data to evaluate consistency of data and to determine impact of EV charging (and discharging) on grid in relation to house loads
    - Real-time assessment of loads on distribution transformers using data described above

Expected Outcomes

- Improved communication, standardization, and interoperability amongst charging infrastructure and grid infrastructure

- New charging technology solutions
- Improved grid planning tools
- Improved protection of grid infrastructure

Metrics and Performance Indicators

- Number of EVSEs and EVs tested for interoperability
- Number of kWh of EV charging load shifted through incentivized, managed charging
- Ability to accurately detect EV charging loads
- Ability to utilize alternative network connections for transmission of smart meter data and the subsequent ability to protect distribution assets from overloads due to EV charging

Primary Users and Beneficiaries

- **Ratepayers** will benefit from being able to charge their EVs when and where they want sooner and with greater ease.
- **Grid operators** will benefit from this topic by using the contribution of grid connected EVs to ensure reliability, safety, and stability.
- **Under-resourced communities** will benefit from lower local emissions and improved grid reliability as well as increased resiliency through V2X-capable EVs.
- **Technology developers and manufacturers** will benefit by testing and offering new equipment and services to assist in the rapid deployment of EVs.

Guiding Principles

- **Safety:** A grid that integrates bidirectional EVs where and when they are needed, without overload or ignitions, delivers on safety.
- **Reliability:** Reliability will be enhanced by grid supportive EVs.
- **Affordability:** By combining bidirectional EVs and emerging grid management systems, grid upgrades can be avoided, leading to increased affordability.

- **Environmental Sustainability:** Transportation electrification reduces internal combustion engine emissions, improves air quality throughout PG&E's territory, and contributes to company and state-wide goals for environmental sustainability.
- **Equity:** Disadvantaged and low-income communities will be targeted for demonstration to help with transportation electrification and attendant benefits from it in those communities. Since DACs might not have the high penetration of EVs that would be needed as the basis to conduct the demonstrations, PG&E will look for opportunities to align EPIC funds with resources from other customer programs and upcoming Federal funding opportunities to provide communities with the EVs needed as the basis for the demonstrations. As part of local demonstrations, PG&E will explore partnership opportunities with community-based organizations to better understand a community's barriers to accessing EVs, prompt recommendations for EV charging at single-family and multi-family homes, and facilitate two-way education between PG&E and the specific community.

Background, Previous Research, and Technology Trends

Small pilots have already been completed that confirm EVs can contribute to market mechanisms which support grid services. However, many other opportunities have not been addressed:

- Standardization and interoperability amongst charging infrastructure would both create greater customer engagement as well as speed EV adoption.
- Innovative charging infrastructure technology solutions such as buffered and wireless charging, as well as battery swapping pose benefits to EV operators and the grid alike.
- Integration of EV data and capabilities into grid planning tools would help identify and visualize short-, medium-, and long-term EV adoption trends that can also be shared publicly with charging station developers which also consider environmental and equity goals.

- Planning tools which enable large-scale commercial fleet operators to quickly add multiple megawatts of load at various locations, especially along major transportation corridors.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	**Topic Applicable**
Grid Operations/Market Design	●
Generation	●
Transmission	
Distribution	●
Demand-Side Management	●

14. Electric Vehicle Battery Re-Use for Stationary Energy Storage

Innovation Need

PG&E has set a goal to deploy at least 500 MWh of second-life electric vehicle (EV) batteries for grid-connected energy storage as part of its 2030 Climate Goals[22], providing a low-cost flexible resource to PG&E and enabling customers to maximize the value of their EVs by lowering the total cost of ownership through an end-of-life value pathway. Batteries retired from EV use are available today and as California moves to 100 percent new sales of Zero Emissions Vehicles (ZEV) by 2035, every year an increasing amount of EV batteries will be retired and become candidates for re-use. Although there has been prior research by the CEC including limited demonstration of smaller-scale second-life batteries in California, PG&E needs to learn how to

22. Pacific Gas and Electric Company. 2022. PG&E Climate Strategy Report. https://www.pge.com/pge_global/common/pdfs/about-pge/environment/what-we-are-doing/pge-climate-goals/PGE-Climate-Strategy-Report.pdf.

economically procure, interconnect, and safely operate larger grid-scale second-life battery storage system to meet its 2030 Climate Goals.

Description

PG&E seeks to conduct demonstration and analysis to identify key utility requirements for the efficient and effective deployment of second-life batteries as grid scale resources. Through the demonstrations PG&E will:

- Generate insights for the most economical methods of siting, deploying, and safely operating grid scale second-life battery storage systems
- Explore use cases for second-life projects (e.g. wholesale energy, peak load, distribution support)

PG&E has already begun to coordinate with the CEC on this topic to ensure that we leverage all of the prior work of the CEC in this area to inform our demonstrations and will explore the possibility of pursuing a joint effort with the CEC, in which the CEC funds a vendor to develop and configure a demonstration-ready grid scale system, and PG&E funds the siting and necessary “make-ready” integration work. PG&E will also collaborate with SCE and SDG&E on second-life battery energy storage system demonstrations to ensure information sharing and non-duplication of work.

Expected Outcomes

Through one or more demonstration projects, PG&E seeks to identify the path to production needed to meet its 2030 Climate Goal of repurposing at least 500 MWh of second-life batteries for grid-connected energy storage. This may include:

- Evaluation of the acquisition, deployment and operational processes for second-life battery energy storage systems
- Analysis of second-life battery energy storage ownership and contracting models
- Identification of the operational roles and responsibilities and potential needed changes to standards and work methods to deploy at scale

- Analysis of potential resiliency and reliability improvements for the customer and the grid brought by second-life battery energy storage
- Understanding the customer journey for end-of-life EV battery monetization

Metrics and Performance Indicators

- MWhs of second-life batteries used for grid-connected energy storage
- Percent availability (uptime) of second-life battery energy storage

Primary Users and Beneficiaries

- **Customers** with an EV battery at the end of its useful service life benefit from being able to sell the EV battery to the second-life grid-connected energy storage market, avoiding disposal costs. PG&E customers would also benefit from lower energy bills as grid-connected energy storage built with second-life batteries may be less expensive than that built with new batteries.
- **IOUs** will benefit from knowing how to safely and cost-effectively interconnect and operate second-life battery energy storage at grid scale.
- **Grid operators** will benefit from the additional reliability and resiliency benefits of this second-life battery-powered grid-connected energy storage.
- **Regulators and planners** will benefit by being informed on potential policy needed to maximize value and reliability of second-life batteries, including but not limited to additional safety standards that may be needed.
- **Technology developers and manufacturers** will have greater certainty in the value of second-life energy storage and the commercialization and scaling needed to support the rapidly growing second-life battery market. Our feedback, in particular for safety standards and grid interconnection procedures, will help technology developers and manufacturers mature and improve their offerings.

Guiding Principles

- **Reliability:** Grid-connected energy storage enabled through second-life batteries will improve reliability and resilience on the electric grid.

- **Affordability:** As part of a circular economy, there will be valuable second-life uses for EV batteries, lowering total cost of ownership of the EV and the cost of grid-connected energy storage.
- **Environmental Sustainability:** Diverting EV batteries for second-life re-use reduces the environmental effects from the mining and processing of battery materials as well as disposal.
- **Equity:** PG&E will explore the viability of deploying second-life battery energy storage systems in locations that benefit disadvantaged and low-income communities specifically, as well as opportunities for the second-life battery energy storage system vendors to coordinate the procurement of the batteries needed for the demonstrations from these same communities. As part of local demonstrations, PG&E will facilitate knowledge sharing between PG&E and local community-based organizations to further understand how second-life battery energy storage system can improve local energy resilience.

Background, Previous Research, and Technology Trends

The CEC currently has four projects (funded thorough GFO 19-310) that are improving battery second life technologies and demonstrating performance in behind-the-meter (BTM) applications to build market confidence. Those projects are:

- Low-Cost and Easy-to-Integrate Second-Life Battery Heterogeneous Unifying Battery (HUB)[23]
- Reuse of Electric Vehicle Batteries for Solar Energy Storage[24]

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23. https://www.energizeinnovation.fund/projects/low-cost-and-easy-integrate-second-life-battery-hub

24. https://www.energizeinnovation.fund/projects/reuse-electric-vehicle-batteries-solar-energy-storage

- Cost Effective Integration of Second-Life EV Batteries with Solar PV Systems for Commercial Buildings[25]
- Enabling EV Battery Circular Economy[26]

These CEC projects each include: 1) controlled laboratory testing and accelerated aging of various used EV batteries to better characterize and predict degradation and remaining useful life during second use, and 2) behind-the-meter demonstrations of second-life battery systems to integrate local solar PV generation and provide backup power during outages with small to medium commercial customers. These projects are generally deploying systems with several hundred kWh capacity, and there may be opportunities to advance these technologies to larger utility-scale applications.

Barriers faced by companies commercializing solutions include the proper assessment of state of health and safety profile of re-used batteries as well as the monitoring and analysis of degradation values of batteries once placed into second-life use. These factors and others directly impact the cost-effectiveness, supply chain formation, availability, durability, and safety of second-life battery energy storage system deployment in front-of-the-meter (FTM) applications at grid scale. The learning from the CEC's present BTM projects will be leveraged for the grid scale FTM demonstrations that PG&E aims to conduct for this topic, preferably in collaboration with the CEC.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	**Topic Applicable**
Grid Operations/Market Design	

25. https://www.energizeinnovation.fund/projects/cost-effective-integration-second-life-ev-batteries-solar-pv-systems-commercial-buildings
26. https://www.energizeinnovation.fund/projects/enabling-ev-battery-circular-economy

Generation	
Transmission	●
Distribution	●
Demand-Side Management	●

CHAPTER 4: Inform California's Transition to an Equitable, Zero-Carbon Energy System That Is Climate-Resilient and Meets Environmental Goals

As California transitions to an equitable, zero-carbon energy system, PG&E must ensure that the grid is resilient and reliable in the face of climate change, and support California's and its own environmental goals. The EPIC program can be instrumental to providing the sustained investment needed for technology development and demonstration to address the significant challenges ahead to arrive at this future. This Strategic Objective contains the single Climate and Environment initiative.

Climate and Environment Initiative

PG&E's nine topics in this initiative are wide-ranging and include new modeling, new and emerging equipment, new inspection and analysis methods, new operational processes, and new ways of interacting with customers.

15. Preventing Faults from Causing Ignitions

Innovation Need

In recent years, climate change has caused a significant increase in wildfire risk within California and across the western United States. In response, and as described in its annual Wildfire Mitigation Plans, PG&E has employed extensive efforts to enhance its understanding of dynamic risk and the health of its assets, and to reduce the occurrences of asset failures and faults in high fire risk areas. While PG&E continues to work to minimize the occurrences of faults, it will not be able to completely prevent faults from occurring and has also taken steps to reduce the risk of faults causing ignitions and wildfires.

A primary method of reducing the risk of faults causing ignitions and wildfires is through rapid de-energization when a fault or potential problem is detected. For example, PG&E is broadly modifying the settings and increasing the sensitivity of its existing protective devices through its Enhanced Powerline Safety Settings (EPSS) initiative, to automatically de-energize powerlines when potential problems are detected. Through the EPIC 3.15 - *Proactive Wires Down Mitigation* project, PG&E is also demonstrating novel substation-based Rapid Earth Fault Current Limiter (REFCL) technology that has the potential to rapidly reduce current to less than an amp for specific types of faults on distribution circuits. While these are examples of viable rapid de-energization capabilities, there are still opportunities to enhance overall capabilities to reduce false positive and negatives, address specific types of faults that pose challenges for current solutions, increase the speed of de-energization, and reduce overall solution deployment costs. Beyond rapid de-energization capabilities, there are also potentially other opportunities for innovation to prevent faults from causing ignitions. These include novel technological methods of removing or modifying vegetation fuel from under our rights of way, new materials for coatings to self-extinguish arcs, as well as alternative conductor materials.

Description

Through this topic, PG&E will demonstrate a wide range of technologies for preventing faults from causing ignitions. A major area of focus will be on capabilities that can either rapidly de-energize or drastically reduce current just after faults have occurred, as well as sensing technologies with edge computing that can de-energize lines just before external objects make contact with our assets and cause faults. PG&E will explore de-energization technologies that are capable of detecting and responding to high-impedance faults as well as lower-voltage faults in the secondary system, which have historically been challenging for existing solutions to address. Examples of rapid de-energization technologies include accelerometers mounted to powerlines that can detect a falling line before it hits the ground, syncrophasor-based fault detection, and real-time edge processing of Light Detection and Ranging (LiDAR) sensors that can anticipate contact with external objects and de-energize just before contact and resulting faults occur.

Beyond rapid de-energization solutions, this topic will also demonstrate solutions for efficiently and potentially autonomously removing vegetation on the ground along PG&E rights of way, new technologies for securing conductors, dynamically adjusting protection parameters in real time based upon conditions, new material coatings for assets to self-extinguish arcs, or even fundamentally new high temperature superconducting conductors that do not pose the same risk of ignition in wire down events.

New technologies will initially be evaluated in a non-operational environment. These technologies will be objectively compared not only to each other, but to currently available solutions such as EPSS and REFCL. To some extent, technologies may be alternatives, but it is also likely that they will present opportunities to improve the functionality of current solutions, and combinations of technologies may provide the best overall risk-reduction solutions. The field demonstrations through this topic may thus employ new technologies in isolation, or combinations of new and existing technologies.

Expected Outcomes

The following are the expected outcomes of the demonstrations conducted through this topic:

- Objective evaluation and comparison of various vendor products at PG&E’s Applied Technology Services lab
- Improvements to various vendor products
- Field demonstration at limited geographic scale within high fire risk areas of one or more solutions, for the primary distribution system and potentially the secondary system
- Incorporation of successful solutions into PG&E’s Wildfire Mitigation Plan, for broader-scale piloting and rollout after EPIC

Metrics and Performance Indicators

- False positive and false negative rates for de-energizations

- Average time between a fault and de-energization
- Percent reduction in the number of faults that cause ignitions

Primary Users and Beneficiaries

- **General public** will benefit from improved safety and air quality that results from fewer ignitions and wildfires
- **IOUs** will benefit from a more effective and efficient set of measures to manage the risks in their systems
- **Under-resourced communities**, and in particular communities at the wildland-urban interface, will benefit from reduced risk of wildfires and the associated risk of widespread destruction in their communities
- **Technology developers and manufacturers** will benefit from learnings gained through technology demonstrations that will help them enhance their product offerings

Guiding Principles

- **Safety:** Preventing faults from causing ignitions prevents wildfires, and the associated public safety risk and destruction they can case
- **Reliability:** New technologies have the potential to reduce false positive de-energizations, and be more precise with turning off customers' power only when necessary
- **Affordability:** Preventing wildfires prevents the widespread destruction and associated economic impacts they can cause
- **Environmental Sustainability:** Preventing wildfires prevents the high amounts of pollutants they release into the environment
- **Equity:** New technologies can be deployed in vulnerable communities at the wildland-urban interface, reduce the inequitable risks faced by those communities, and reduce the inequitable impacts of air quality they face during wildfires

Background, Previous Research, and Technology Trends

Ignition probability for a fault is primarily a function of the fault energy and contact with dry fuel. The fault energy is composed of the fault current for a given duration. Reducing the fault current or the duration of the fault reduces the energy and the probability of ignition. EPSS is a tool which reduces the duration of faults by using very short time delays for tripping line protective devices. The downside to EPSS has been an adverse impact to reliability with increased SAIDI and SAIFI. The standard practice during fire season is to disable automatic reclosing, so once an EPSS enabled device trips, it locks out even if the fault was momentary.

Energized wire down scenarios on PG&E's distribution circuits pose a public safety and fire ignition risk. These scenarios are difficult for conventional distribution protection schemes to detect and de-energize the wires on the ground, since PG&E's existing distribution protection scheme relies on detecting high fault current to trip protective devices. This detection scheme can respond too slowly to prevent a fire ignition from an energized wire down or may not detect the energized wire down at all in the case of a high impedance fault. REFCL has high sensitivity to ground faults and limits fault currents below 0.5 Amps, but it is technically challenging to implement and operate.

The use of 3D LiDAR technology in and of itself is not a new and innovate technology, however in the case of wildfire mitigation, implementing 3D LiDAR technology to identify approaching vegetation is a new way to implement this technology for wood pole infrastructure. PG&E has explored 2D LiDAR and has proven its effectiveness with identifying approaching trees prior to making contact with a live conductor. There are limitations with 2D LiDAR though which 3D LiDAR would address. Benefits of 3D LiDAR over 2D LiDAR are: placement of device can reside below the conductor line, reduction in the number of devices required to fully encapsulate the conductor line, ease of installation, simplicity of design, increased system reliability, reduction of maintenance costs, and power reduction. However, for any real-time LiDAR-based approach to monitoring and proactive de-energization, significant work would need to be done to develop and demonstrate a solution that is economically viable to deploy at a broad scale.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	
Generation	
Transmission	●
Distribution	●
Demand-Side Management	

16. Undergrounding Capabilities

Innovation Need

Meeting our state's climate challenges requires bold, innovative action. That is why PG&E has launched the largest undergrounding effort by a US utility, the undergrounding of 10,000 miles of distribution system powerlines located in or near high fire-threat areas, specifically to reduce wildfire risk.

While PG&E has begun to implement its undergrounding plan using existing technology solutions, there are novel ideas and emerging technologies that have the potential to increase the speed, efficiency, and predictability of undergrounding, as well as potentially extend the life of assets with intelligent monitoring. Improvements in these areas would lead to lower costs for customers, quicker reduction of wildfire risk in these areas, and maintaining longer asset life, without jeopardizing safety and reliability.

Description

PG&E will conduct technology investigations and conduct demonstrations for the following as part of this topic:

- At-surface Alternatives to Undergrounding: When excavation is required to underground certain areas of the system, it typically requires a more stringent permitting process with longer lead times or more costly construction methods. While best efforts are made in the design phase to avoid these constraints, in some cases it is not feasible to sufficiently alter route design to avoid these areas and the associated additional costs or extended permitting period. These at-surface alternatives would be used as a permanent solution, as well as for rapid deployment in emergency situations and speedy temporary rebuild after damage including from fire damage. As part of its efforts to reduce costs and increase the speed of undergrounding and restoration, PG&E will evaluate and demonstrate novel at-surface alternatives.
- Advancing Subsurface Mapping Technologies: Though significant advances have been made in subsurface mapping technology, existing methods remain unable to provide a highly accurate and comprehensive view of subsurface conditions. Even cutting-edge technologies, such as ground penetrating radar (GPR), that can more accurately detect variations in subsurface conditions require significant human effort to interpret results, rendering the technology cost-prohibitive for widespread use. As part of efforts to improve the accuracy of subsurface maps created during the undergrounding process, PG&E will evaluate and demonstrate novel at subsurface mapping technologies.
- Intelligent Monitoring of Underground Distribution Lines: The technology installed to monitor underground utility infrastructure in most cases is reactive, rudimentary, and wholly insufficient to effectively manage a vast network of cables over the course of the asset’s life. These shortcomings can result in unobserved deteriorations that can lead to faults and unplanned outages. PG&E along with other US utilities have started looking at novel technologies for evaluating the condition of the underground system and predicting impending failures. These technologies include novel wired and wireless, communicating sensors with long maintenance-free lifetimes that combined with machine learning capabilities to be able to predict impending failure so that corrective action can be taken to prevent unplanned outages.

- Cost-effective Reduction and Management of Spoils from Underground Excavation: Undergrounding construction unavoidably disturbs soil at the site, generating excess spoils that must be properly disposed of. These spoils must be handled according to specific requirements and often must be hauled off-site for processing, remediation, or disposal. Moving soils back and forth for processing and disposal between off-site locations that are often far from dig sites requires time and resources that could be avoided, aiding affordability. This process is particularly costly in cases where disturbed soil contains hazardous materials. To increase affordability and reduce the environmental impact of handling spoils, PG&E will evaluate and demonstrate new at-site and other spoils management technologies.
- Novel Materials/Construction Methods for Undergrounding: The labor required for boring tunnels, excavating trenches, laying conduit, and pulling and splicing cables drives the majority of undergrounding costs. While some innovation has been made in these areas, the methods and materials used have remained largely unchanged for years. To reduce costs and help expedite undergrounding, PG&E will evaluate and demonstrate emerging construction materials and methods. Examples include: new types of conduits that allow far longer cable pulling distances between connecting enclosures; on-demand custom 3D printed structures that allow greater flexibility in routing around obstacles and in narrow or restricted rights of way; novel solutions for siting underground distribution switches, line reclosers, and regulators; new low-cost technologies for connecting secondary service to the underground system; and methods for minimizing the need for imported aggregate materials.
- Underground Resonant Grounding: This type of grounding can offer a number of safety improvements particularly for underground vaults. While widely used in Europe, underground resonant grounding is not common with North American utilities, and PG&E has no experience using it. PG&E will investigate applicability and demonstrate underground resonant grounding technology on PG&E's system.

PG&E has been and will continue to work alongside its fellow EPIC Administrators to coordinate on EPIC topics and projects to ensure non-duplication of work, to be able to collaborate on projects when possible, and to share project learnings. PG&E notes that SCE's Hardening and Remediation topic in their EPIC 4 Investment Plan includes elements that, at a high level, overlap with elements of this topic, though SCE's Hardening and Remediation topic is much broader than this topic. PG&E and SCE will continue to work together to ensure that undergrounding-related projects that may be pursued through their respective topics are aligned and avoid duplication.

Expected Outcomes

The following outcomes are expected:

- A viable at-surface alternative to certain types of undergrounding where excavation would otherwise be required
- More accurate subsurface mapping with a path to operationalization
- Improved underground distribution lines sensors and systems along with analytics for advanced condition monitoring and predictive maintenance capability
- Cost-effective solution for reducing and better managing underground excavation spoils
- At least one novel material or construction method for undergrounding along with a path to production plan
- Demonstration of a viable underground resonant grounding technology that improves upon the state-of-the-art underground grounding systems currently available

Metrics and Performance Indicators

- Amount of excavation avoided through at-surface solutions
- Percent accuracy improvement of subsurface maps
- Number of cable deteriorations or faults detected that otherwise would not have been found through existing monitoring systems
- Cost reduction from improved excavation spoils management
- Number of novel materials or construction methods demonstrated

Primary Users and Beneficiaries

- **Customers** would benefit from the reduced wildfire risk and service reliability improvement from a faster, smarter, more cost-effective undergrounding program.
- **IOUs** would benefit from simpler, more predictable undergrounding projects.
- **Grid operators** would benefit from higher visibility into underground infrastructure condition and ability to proactively maintain the equipment for greater reliability and safety.
- **Under-resourced communities** in high fire risk areas would benefit from an earlier reduction in wildfire risk from faster completion of undergrounding projects.
- **Technology developers and manufacturers** would benefit from having their emerging products evaluated and demonstrated and would be able to improve their products through demonstration experience and utility feedback.

Guiding Principles

- **Safety:** A simpler, more accurately mapped, project with fewer labor hours reduces uncertainty and exposure, and therefore is safer.
- **Reliability:** A better monitored and maintained undergrounding system provides more reliable service.
- **Affordability:** By reducing project cost, including labor hours, the undergrounding program is more affordable.
- **Environmental Sustainability:** A more accurate, more efficient undergrounding process requires fewer resources and enhances the environmental sustainability of the program.
- **Equity:** Vulnerable communities in high fire risk areas could have service undergrounded sooner than otherwise would be possible, reducing their exposure to wildfire risk as well as the resulting risk of potential loss of work, education, childcare.

Background, Previous Research, and Technology Trends

Although PG&E and many other utilities have existing, extensive underground distribution networks, the terrain and soil composition as well as other environmental and other factors make the conventional undergrounding processes extremely difficult or expensive in certain areas, including in the high fire risk areas within PG&E's service territory. Alternatives need to be explored to make installation more effective.

Fault sensing and protection against transient voltages is another area where research is showing opportunities to increase expected average life of assets. Real-time monitoring is an opportunity to see the asset's health with a plan to make proactive repairs before the asset is damaged and fails in service.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	**Topic Applicable**
Grid Operations/Market Design	●
Generation	
Transmission	●
Distribution	●
Demand-Side Management	

17. Improved Inspection Capabilities

Innovation Need

PG&E collects a wide range of data for its routine inspections through a variety of collection methods, but its processes for reviewing the collected data are almost entirely manual. Manual inspections of assets are costly, and the quality of results can vary from inspector to inspector. Processes can be made more efficient, effective, and verifiable through application of automated machine learning capabilities. PG&E has begun to develop preliminary AI technology for inspections through its Waldo platform, but it is currently limited in the types of asset deficiencies and components it can identify and has been primarily focused on Transmission system assets. Waldo also currently lacks the ability to understand the relationships across images, such as the relationship of multiple images of the same component.

Processes for updating and assessing the quality of asset information in PG&E's systems of record are also largely manual. These processes also lack the ability to gather previously missed data points when we identify new information to capture. For some of the inspection data that is collected, there is also opportunity to populate even more detailed asset attribute information (ex: insulator counts, types, etc.) in our systems of record, but this would only be feasible with additional computer vision model development and focus.

While PG&E already collects a wide range of data types for inspections, there is potentially opportunity to employ new sensors to collect additional data types to help PG&E further improve its understanding of the health of its assets and the risks along its rights of way. There is particularly opportunity around failure modes that begin to manifest within assets and are not externally apparent.

Description

This topic will demonstrate capabilities for leveraging existing inspection data and machine learning to automate inspection processes, as well as processes for updating asset records. The topic will also demonstrate new sensors that can improve the early identification of various asset failure modes.

PG&E has an extensive amount of data including imagery, video, and Light Detection and Ranging (LiDAR), other data that can help with understanding of image relationships, as well as metadata associated with each of these data types. It is collected from the ground as well as manned and unmanned aircraft for inspections of its assets and the surrounding vegetation. PG&E will leverage these and potentially other data sources to demonstrate machine learning-based capabilities for automating the inspection and issue identification process. Work in this area will build upon the preliminary capabilities in PG&E's Waldo platform. Waldo is currently only being used for the transmission system, and this topic would both build capabilities for transmission and expand into distribution. As part of this effort, PG&E will explore ways for Waldo to understand relationships between multiple images (e.g., the insulator in picture 1 is the same insulator as that in picture 2, and "this structure contains X count of insulators").

Asset issues for which to automate identification include pole lean and deficiencies in C-hooks, insulators, hanger plates, and potentially numerous other issues.

PG&E will also apply this broad array of data to demonstrating capabilities for automatically identifying assets, their precise locations, and their detailed attributes, then updating asset information in the official systems of record.

Beyond automating inspection processes and updates to asset records, this topic will explore new sensors and data elements to improve the early identification of various asset failure modes. Demonstrations in this area will focus primarily on failure modes that begin to manifest within assets and are not externally apparent. Examples that may be pursued include ultrasonic sensors, which may help to identify internal corrosion in steel poles, and X-Ray devices, which may help to identify issues in transformers such as low oil levels.

Expected Outcomes

The demonstrations conducted through these topics are expected to deliver the following outcomes:

- Enhancements to PG&E's Waldo platform and field inspection tools to automate inspection processes
- Enhancements to PG&E's Waldo platform and field inspection tools to quality check/review human inspection results
- Enhancements to PG&E's Waldo platform and field inspection tools to detect potential failure-causing damage much closer to image capture, then escalate inspections accordingly
- Enhancements to PG&E's Waldo platform and field inspection tools to quality check/review and ultimately automate the quality of image data captured (e.g. blurry images, structure photographed does not match structure of corresponding digital record, etc.)
- Processes and interfaces to asset systems of record to automate asset information updates in those systems

- Processes and interfaces to asset systems of record to quality control existing structure, asset, and failure data gathered by non-computer vision sources
- New sensors incorporated into PG&E's inspection practices to better identify incipient asset failures

Metrics and Performance Indicators

- Rates of true and false positives for asset issues flagged in automated inspections
- Rate of errors in automatically updated asset records
- Decrease in time between image capture and identification of assets and damage with computer vision vs. without
- Decrease in cost to identify assets and damage with computer vision vs. without
- Number of asset issues that can be identified by new inspection sensors that could not be identified through existing means

Primary Users and Beneficiaries

- **Customers** will benefit from greater reliability due to more effective inspections and identification and handling of system issues before they can result in outages. They will also benefit from cost reductions due to the reduced Utility operating costs from replacing manual labor-intensive inspections with automated methods.
- **IOUs** will benefit from more efficient and effective inspection processes, reduced system risk and reduced operating costs.
- **Under-resourced communities** will benefit from greater reliability and reduced exposure to hazards, particularly in the wildland urban interface.
- **Technology developers and manufacturers** will enhance their product offerings as a result of the feedback gained from the demonstration of their various sensor devices.

Guiding Principles

- **Safety:** More effective inspections and identification and handling of system issues can prevent potential catastrophic asset failures, and potentially wildfire ignitions, that would put PG&E's workforce and the public at risk.

- **Reliability:** Enhancements to proactive identification of asset risks and issues allows for proactive mitigations, which prevents failures that would cause customer outages.
- **Affordability:** Automating inspection processes will not only reduce manual labor, it also has the potential to improve the overall effectiveness of inspection processes, and addressing issues before they result in failures is less expensive than repairing or replacing failed assets.
- **Environmental Sustainability:** Improving inspections to better proactively identify and address asset issues will reduce failures that could cause wildfires.

Background, Previous Research, and Technology Trends

Waldo, PG&E's AI-informed inspections platform, was initially developed to identify damage to electric transmission structures and the assets on them, then flag this damage for human review through PG&E's Sherlock remote desktop inspection application, as a step towards the ultimate goal of fully automating inspections. In addition to many other non-AI related challenges, the initial data pipeline and AI model design struggled with accuracy. The Waldo team has addressed some of the challenges and adjusted its roadmap and product vision. Waldo is now being used to automate some limited aspects of inspection processes, such as gathering information on assets like insulator material and color, but assessment of asset damage is still done manually. The Waldo team has also developed ways to measure AI performance against human inspection results, which will help to evaluate the performance of automated inspection capabilities demonstrated through this EPIC topic.

PG&E collects a wide range of data types for inspections, including pictures, video, LiDAR, infrared, and other data elements. However, there is opportunity to employ new mobile sensors to collect additional data types to help PG&E further improve its understanding of the health of its assets, particularly for failure modes that begin to manifest within assets and are not externally apparent. Through the EPIC 3.46 - *Advanced Electric Inspection Tools* project, for example, PG&E is exploring the application of portable x-ray devices to detect rot in a utility wood poles, and there is opportunity to explore whether these same devices could be valuable for broader asset inspections, such as determining the oil level of transformers, or other uses.

Other types of sensors or methods may be able to detect other internal failure modes that are difficult to detect, such as corrosion in steel poles.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	**Topic Applicable**
Grid Operations/Market Design	
Generation	
Transmission	●
Distribution	●
Demand-Side Management	

18. Pinpointing Fault Location

Innovation Need

While PG&E has numerous methods for identifying when there is a fault in its electric system, it can be difficult to determine the precise location of the fault. The time it takes to identify the fault location and cause slows service restoration for customers from unplanned outages as well as from EPSS events. Outages are not just inconvenient for customers, but also bring economic and public safety impacts. There is a need to improve current capabilities to provide more reliable service for our customers and the general public.

Description

This topic will demonstrate a range of new methods for determining fault location, such as using the precise timing signals available from third party fiber optics cabling located alongside to PG&E distribution lines, next generation line sensors, SmartMeters, and synchrophasors.

This topic will also demonstrate technology currently used to pinpoint the location of faults in underground transmission lines to evaluate whether it can be effective in detecting fault locations for overhead transmission lines, as well as demonstrate novel technology for determining distribution fault location by analyzing fault and mid-circuit voltages using a combination of data from existing sensors as well as from new sensors and SmartMeters.

Beyond developing methods to narrow down the geographic location of faults within the system, this topic will also explore methods for locating the specific locations of deterioration and faults within assets themselves. For example, partial discharge events in power transformers pose significant reliability as well safety risk. One way to identify potential impending catastrophic failure is through sound. This topic will demonstrate the use of multiple acoustic sensors placed on a power transformer to determine if partial discharge faults within the transformer could be precisely located. The acoustic events would be analyzed to determine not just location but size and potential severity to provide guidance on the urgency of actions needed to be taken with that transformer to avoid unplanned service interruptions. A second way to detect partial discharge events in power transformers could be through fiber optics. This topic would also demonstrate the application of fiber optic cabling to existing power transformers along with analytics to determine if these partial discharge events could be detected. Radio frequency monitoring and imaging of the power transformers would also be demonstrated to evaluate efficacy of these technologies. Depending upon the success of any of these methods on power transformers, they may also be demonstrated on certain service transformers serving critical or public safety loads.

Expected Outcomes

This topic is expected to result in the following outcomes:

- Demonstrations of novel technologies for more rapidly determining fault location in PG&E’s transmission and distribution conductors
- Demonstrations of novel technologies for sensing and locating partial discharge events within power transformers
- Informing of strategy and path to production plans for technologies that cost-effectively improve upon speed and accuracy of fault location

Metrics and Performance Indicators

- Average distance between predicted location of fault and actual location
- Reduction of the number of average minutes of determining the exact fault location in comparison to standard operational practices
- Number of partial discharge events detected and located in power transformers

Primary Users and Beneficiaries

- **Customers** will benefit from fewer outage minutes that they experience in their electric service.
- **IOUs** will benefit from being able provide more reliable electric service to their customers.
- **Technology developers and manufacturers** would benefit from feedback on their technologies so that they can improve their products; ultimately benefitting customers.

Guiding Principles

- **Safety:** The reduction of outage minutes resulting from the solutions developed and demonstrated through this topic will improve public safety.
- **Reliability:** Shorter power interruptions help improve service reliability.
- **Affordability:** Customers will experience shorter outages thereby reducing the economic impact of outages, making service more affordable.

Background, Previous Research, and Technology Trends

Much effort has been made previously to identify fault locations more quickly and accurately. Approaches using dispersed fault indicators to calculate fault location based on fault magnitude and circuit model have been attempted with some success, but investment costs and lagging technology have been impediments to greater success. With the advancement of distributed sensors, edge analytics, improved telemetry, and other novel approaches, these approaches are now becoming more within reach. Also, major advancements in smart meters are enabling the use of these widely deployed devices as edge sensors to help localize grid events. Other self-monitoring telemetry technologies that can be incorporated into new assets will help further improve reliability, though need demonstration.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	
Generation	
Transmission	●
Distribution	●
Demand-Side Management	

19. Risk Modeling Improvements

Innovation Need

In recent years, PG&E has made strides to enhance its ability to understand system risk and make objective investment and operational decisions aimed at maximizing risk reduction. For example, PG&E has developed and applied a system risk model in support of its annual Wildfire Mitigation Plan (WMP) that is used to quantify and objectively compare the risk that is reduced by each of the initiatives and mitigation measures proposed in its plan. PG&E also applies risk models to support operational decision making, such as real-time decisions on whether Public Safety Power Shutoffs (PSPS) need to be implemented in response to dynamic environmental conditions. In addition to these applications, PG&E risk models are an important element for annual emergency response exercises and development of realistic planning scenarios.

While PG&E has made strides, there is significant opportunity to continue improving its risk modeling capabilities in a number of areas. There is opportunity to improve and expand upon the underlying asset information that the models use. There is also opportunity to make models more granular to provide more granular calculation of risk spend efficiency across potential mitigations, and support more detailed investment decisions, such as whether to underground short sections of overhead distribution instead of other mitigations, or whether to underground secondary circuits as part of larger undergrounding projects.

In addition to enhancing the underlying asset information and improving the granularity of risk models, there are also opportunities to improve PG&E’s various underlying environmental forecasting capabilities. For example, PG&E's wind forecasting is a primary component of wildfire risk modeling and is currently done with 2km resolution. Higher-resolution, accurate, wind data has the potential to significantly improve various PG&E processes, including PSPS planning and implementation. Various vendors have proposed technologies and approaches that they claim can reliably improve the resolution of PG&E’s current wind forecast data, but it is challenging to objectively compare the respective merits of the various vendor offerings without conducting thorough demonstrations. In addition to improving the underlying data that drives wildfire risk modeling, there is also opportunity to improve the modeling of non-wildfire risks to PG&E infrastructure such as volcanic eruptions, earthquakes, landslides, debris flows, drought, and other events.

Description

This topic will demonstrate capabilities for enhancing the underlying asset information and making risk models more granular, providing more granular underlying weather modeling, as well as modeling of a wider range of potential natural disasters.

PG&E will explore methods of improving and expanding upon the underlying asset information that its risk models use. PG&E will also demonstrate ways to make its risk models more granular, to support more detailed selection of the most appropriate mitigation measures in narrower geographic areas. An ultimate objective is to develop a full digital twin of PG&E’s system, which would provide a common virtual model that encompasses geospatial, technical, physical, and operational information that would be accessible enterprise-wide to support myriad applications and personnel. The work through this topic would help set the foundation for such a capability.

Examples of inputs for the digital twin could include GIS information, vegetation land surveys, engineering asset database, and high-resolution LiDAR data. Together this data, for instance, could build a virtual “3D” digital model of a line segment by representing pole spacing, line spacing, vegetation clearance, and mechanical and electrical properties. PG&E's weather applications could feed wind data into this model, where other engineering application(s) could calculate line swing and risk of ignition (based on the last clearing time and growth calculation from the vegetation database). PG&E’s ADMS application could automatically identify a PSPS event by processing the model's ignition risk parameters.

With respect to improving environmental forecasting capabilities, one example demonstration would be to increase the resolution of PG&E’s wind forecasting models. Numerous vendors have approached PG&E and have claimed to be able to reliably forecast wind at resolution below 1km. PG&E would conduct an objective comparison of the wind forecasting capabilities of multiple vendors using common evaluation criteria and datasets from past PSPS events. Beyond improving the forecasting of wind and other weather data that will improve wildfire risk modeling, this topic will also develop capabilities to model and monitor the vulnerability of PG&E electric and gas system to other natural hazards such as volcanic events.

Expected Outcomes

The following are outcomes expected to result from the demonstrations conducted through this topic:

- Initial planning work and foundational demonstrations on the path to ultimately a highly detailed digital twin of the electric system
- More granular weather modeling capabilities, including potentially more granular wind forecasting. Enhanced models are expected to transition into operations at the conclusion of EPIC demonstrations with minimal additional integration costs
- Implementation of new risk models for non-wildfire natural hazards, that will be used both for strategic planning and real-time monitoring

Metrics and Performance Indicators

- Amount of increase in spatial resolution of various weather modeling capabilities
- Amount of additional enterprise risk reduction, which includes wildfire risk reduction, enabled through this topic

Primary Users and Beneficiaries

- **Customers** will benefit from better Utility investment decisions that result from improved risk modeling practices and higher risk reduction for the costs they bear. They will also benefit from improved operational decisions that result from improvements to risk models and underlying weather models, such as through more targeted PSPS implementation.
- **IOUs** will benefit from improved tools that allow them to maximize system risk reduction from their operating budgets and improved operational decision making enabled by improvements to risk models and underlying weather models.
- **Under-resourced communities**, and in particular communities at the wildland urban interface, will benefit from better-informed risk reduction measures that IOUs employ to reduce the risk of fires in their communities, as well as better operational risk models that result in more targeted PSPS activations only when and where needed.
- **Technology developers and manufacturers** may improve their product offerings based on the results and learnings of the demonstrations.

Guiding Principles

- **Safety:** Improved risk modeling capabilities will broadly reduce wildfire and other risks to customer and worker safety.
- **Reliability:** Improvements to risk-informed investment planning will reduce asset failures and unplanned outages. Better operational risk models will result in more targeted PSPS activations and activations of EPSS settings only when and where needed.
- **Affordability:** Improved risk modeling is intended to guide work to mitigate more risk than would otherwise be possible. Less risk leads to fewer catastrophic disasters and therefore lower costs. Improved risk modelling also allows for improved long-term

planning to ensure capital investments are appropriate up front to minimize the long-term costs and need for re-investing in the same areas due to changes in environmental factors.

- **Environmental Sustainability:** Improved risk modeling capabilities will broadly improve Utility risk mitigation measures, which will help to reduce wildfires and other events.
- **Equity:** A disproportionate amount of PG&E's system risk is in communities in the wildland urban interface, and improvements in risk-informed investment planning and operational decision-making will benefit these communities specifically.

Background, Previous Research, and Technology Trends

As mentioned above, in recent years, PG&E has made strides to enhance its ability to understand system risk and make objective investment and operational decisions aimed at maximizing risk reduction. PG&E continues to work closely with its fellow IOUs, the vendor community, and academic institutions in these efforts. Examples include joint Utility modeling, third-party risk model assessments, climate vulnerability assessments, as well as egress, EPSS, fire break, and fire-retardant studies.

Through the EPIC 1.05 - *Demonstrate New Resource Forecast Methods to Better Predict Variable Resource Output* project, PG&E made significant strides to improve the resolution of its weather forecasting capabilities, and also developed a Fire Danger Rating System that served as the basis for PG&E's Fire Potential Index. This project concluded in December of 2016, and there are now opportunities to demonstrate and integrate vendor product offerings for even more granular weather forecasting. In addition to improving the underlying data that drives wildfire risk modeling, there is also opportunity to improve the modeling of non-wildfire risks to PG&E infrastructure. Work in this area could enhance existing tools such as PG&E's Dynamic Automated Seismic Hazard (DASH) system.

In recent years, utilities have been exploring the concept of creating detailed Digital Twins of their systems to support a range of use cases, and just this year PG&E started new discussions with SCE and other major North American utilities on the digital twin definition, the reference model, and use cases. The concept of a Digital Twin Model goes beyond meteorology and environmental forecasts. A Digital Twin would combine geospatial, technical, and physical characteristics together into a common model that could ultimately significantly improve PG&E's understanding of the risks in its system. Examples of inputs for model of this type could include GIS information, vegetation land surveys, engineering asset database, high-resolution LiDAR data, as well as weather data. Many factors are beginning to make a digital twin concept more feasible, including greater access and more efficient means of capturing data such as LiDAR, improvements to the data in PG&E's existing systems of record, and the availability of cloud environments and greater computational power for hosting such complex models. However, creating a Digital Twin would be a significant undertaking that would have to be tackled in steps, with prioritization of specific functional elements and use cases along the way.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	**Topic Applicable**
Grid Operations/Market Design	●
Generation	
Transmission	●
Distribution	●
Demand-Side Management	

20. Crowdsourcing

Innovation Need

PG&E employs a wide range of inspection and situational-awareness resources including field inspectors, drones, helicopters, weather stations, and cameras to enhance its efforts to keep communities safe from wildfire and other hazards. In accordance with I.19-06-015, PG&E has also developed and released its *Report It* app in a pilot phase as an addition to its safety toolkit.

This crowdsourcing app is meant to be used by the public to send photos or videos of non-emergency safety concerns related to electrical equipment, such as vegetation posing a risk to PG&E power lines. PG&E manually reviews the imagery that is submitted to determine whether and what action needs to be taken. There is an opportunity to apply machine learning to the reports currently being submitted, to broaden crowdsourcing to partnerships with companies that may be routinely collecting valuable data in PG&E's service area, and to intake a wider range of data beyond photos and video.

PG&E's current *Report It* app is also not meant to address emergency situations, and there is an opportunity to demonstrate tactical crowdsourcing capabilities that can be applied to support a range of emergency situations.

Description

This topic will demonstrate robust crowdsourcing capabilities to both enhance awareness of potential hazards and issues in non-emergency situations, as well as improve shared situational awareness in tactical emergency situations. Crowdsourcing will involve both the general public, as well as partnerships with private companies that routinely collect a wide range of valuable data types across PG&E's service area. For example, fleets of self-driving cars collect Light Detection and Ranging (LiDAR) data that renders a detailed three-dimensional picture of its surroundings, which may be valuable to PG&E for both the assessment of our assets and the surrounding vegetation.

Beyond broader crowdsourcing and partnerships to increase the volume and types of data available to PG&E, this topic will develop advanced machine learning capabilities for automatic and rapid assessment of these large volumes of data.

This topic will also explore the potential compensation side of crowdsourcing, as well as the corresponding technology foundations, such as blockchain, for facilitating a high volume of micro-transactions that could provide the compensation that would encourage robust participation in the interest of public safety.

Expected Outcomes

The primary expected outcome of this topic is to have crowdsourcing platforms and processes that are ready to transition into real-time operational use between PG&E and a broad range of external participants. This will involve secure data feeds, as well secure financial transactions to the extent that compensation mechanisms are included as part of the model. Processes will also include automated machine learning-based analysis of the external data received, verification of the accuracy of the automated models, and associated clearly-defined, automated, and integrated processes for triaging, tracking, resolving, and communicating resolutions of identified issues.

Metrics and Performance Indicators

- Number or percent of issues identified through crowdsourced information that were confirmed to require intervention
- Number or percent of issues identified through crowdsourced information that were confirmed to require intervention and not otherwise detected internally by PG&E

Primary Users and Beneficiaries

- **IOUs** will leverage crowdsourced information to supplement their own data sources and improve their understanding and management of risks across the system.
- **Customers** will benefit from the cost efficiency associated with IOUs broadly leveraging a rich set of external data without incurring the costs of collecting the data themselves. Customers will also benefit from the resulting reductions in grid issues and ignitions, and improved resolution of emergency situations.

Guiding Principles

- **Safety:** Crowdsourcing information will improve Utility understanding and management of risks across the system, to further mitigate failures that could impact employee and public safety and create ignitions.

- **Reliability:** Crowdsourcing information will improve Utility understanding and management of risks across the system, to further mitigate failures that would otherwise cause outages.
- **Affordability:** Crowdsourcing information to prevent failures that could damage or destroy Utility equipment and potentially cause broader catastrophic events has the potential to result in significant avoided costs. Gathering this information from external parties may also be more cost effective than IOUs collecting the data themselves.
- **Environmental Sustainability:** Crowdsourcing information to prevent failures that may have otherwise resulted in ignitions has the potential to prevent the environmental impacts associated with wildfires.

Background, Previous Research, and Technology Trends

As mentioned above, in accordance with I.19-06-015, PG&E has developed and released its *Report It* app in a pilot phase for customers in high fire threat areas. This initial crowdsourcing capability is being used by the public to send photos or videos of non-emergency safety concerns related to electrical equipment, such as vegetation posing a potential risk to PG&E power lines. PG&E manually reviews the imagery that is submitted to determine whether and what action needs to be taken, without applying any machine learning or automation. PG&E has been building the internal tools and data science expertise that could be leveraged to derive extensive value from this data. While photos and videos are valuable data elements, other data elements such as LiDAR can also be extremely valuable. For example, within California in particular, there has been an increase in fleets of self-driving cars that collect massive amounts of LiDAR data that could be leveraged. Advances in blockchain applications beyond the digital world and into the physical world indicate the feasibility of providing the incentive framework and high volume of micro-transactions that could drive robust participation in any expanded PG&E crowdsourcing efforts.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	
Generation	●
Transmission	●
Distribution	●
Demand-Side Management	

21. Climate and Nature-Positive Operations

Innovation Need

As part of its commitment to climate action in California, PG&E will reduce its carbon emissions by 50 percent for direct and indirect operations and by 25 percent for value-chain activities not owned or directly controlled by PG&E. By 2040, PG&E will achieve a net zero energy system on the way to a climate- and nature-positive energy system by 2050.[27] The overall carbon emission reduction is the result of many contributing actions and investments, with a number of the technologies needed either ready to use or are maturing. The carbon emissions reduction will not be 100 percent by 2040; therefore, in order to achieve a net zero energy system, PG&E or its suppliers will need to also deploy, or at minimum benefit from, cost effective carbon capture, storage, and re-use technologies. There needs to be substantial technology advancement and commercialization improvement so that these technologies are ready for wide-scale deployment and materially contribute to achievement of PG&E's climate plan.

Description

PG&E will assess technology options and conduct demonstrations of climate and nature-positive solutions that, for example, may be applied to any remaining source of PG&E's direct,

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27. Pacific Gas and Electric Company. 2022. PG&E Climate Strategy Report. https://www.pge.com/pge_global/common/pdfs/about-pge/environment/what-we-are-doing/pge-climate-goals/PGE-Climate-Strategy-Report.pdf.

indirect, or value-chain-related carbon emissions. In doing so we will evaluate considerations such as capital costs, at-scale operating costs, net effects, required standards and work method changes, and storage siting and issues.

PG&E will assess technology options, conduct demonstrations, and complete analyses that will provide input and guidance for vegetation-related work. For instance, PG&E seeks to improve operational efficiency, environmental performance, and worker safety across the woody biomass value chain from locational targeting to collection, in situ processing, removal, and development of value-added carbon re-use products. Improved project targeting and scoping for operational and ecosystem benefit, process automation, novel equipment demonstrations, new processes, and/or climate-positive re-use (such as renewable natural gas (RNG), hydrogen, mass timber, bio-oils, biochar, liquid fuels, and carbon sequestration/carbon credits) are potential areas for improvement.

Carbon tracking as a possible component of an EPIC project scope could lead to better understanding of how utility operations can generate verifiable greenhouse gas emissions mitigation or removal for the betterment of our customers and planet. It is possible that EPIC project(s) will reveal that compliance or voluntary carbon market buyers would like to buy into utility-related projects creating positive carbon-attributes, such as those resulting in production of biochar. Such external carbon credit purchases could potentially help co-fund and/or accelerate beneficial wildfire risk reduction work. PG&E does not currently have plans to claim (or purchase) carbon credits through EPIC projects warranting assurance of “credits that are rigorously demonstrable as real, verified, enforceable, permeant, additional, and robust against leakage.” It would be the responsibility of any entity making carbon emission mitigation or removal claims to provide assurance of having met these criteria, with transparency about protocols used in making such claims.

Through this topic, PG&E intends to understand the value, quantity, quality, and characteristics of potential climate and nature-positive opportunity, such as that represented by woody biomass value chain, and potential pathway to scale.

Expected Outcomes

This topic is expected to deliver the following outcomes:

- Demonstrations and path to production guidance for carbon and environment-positive solutions that can be applied to PG&E's direct operations and value chain
- Evaluation and demonstration of location-specific vegetation management (and hazardous fuels removal) work across benefits including wildfire mitigation, rebuild and repair avoidance, electric reliability, electric procurement cost, and/or ecosystem benefit
- Improved woody biomass-related technologies for vegetation management increasing worker and public safety
- Upgrades to woody biomass management technologies improving cost, safety, and environmental outcome profiles (including solutions relevant to cutting, densification, transportation, storage and conversion)
- Thorough understanding of woody biomass processing/conversion technologies mapped to appropriate products to demonstrate the economic and environmental value streams needed to incentivize investment in this nascent industry

Metrics and Performance Indicators

- Percent carbon emissions and/or criteria pollutant reduction enabled through widespread deployment of developed and demonstrated technologies
- Percent reduction in vegetation management worker and vehicle-related safety incidents
- Avoided damage to PG&E assets (e.g., hydro assets at risk of fire, siltation, or mudslide damage)
- Number of tons of carbon removed or offset
- Number of acres benefiting from ecosystem restoration
- Economic value enabled through widespread deployment of the developed and demonstrated carbon re-use technologies

Primary Users and Beneficiaries

- **Customers** will benefit from reduced wildfire risk, from reduced costs (e.g., from operational savings or cost offsets from value-added revenues), and from environmental outcomes (e.g., GHGs, criteria pollutants, ecosystem benefit).
- **IOUs** will benefit from reduced wildfire risk, reduced operational costs (from operational savings, cost offsets from value-added revenues), and improved worker safety.
- **Under-resourced rural communities** could benefit both from improved public safety and potential new economic opportunity associated with climate and environment-positive value chains.
- **Technology developers and manufacturers** will have opportunities to demonstrate climate and nature-positive technology, and to understand the role that utilities could in the play in future market development (e.g., as feedstock provider or offtaker).

Guiding Principles

- **Safety:** Improved vegetation management and nature-positive solutions tend to reduce wildfire risk, and also represent opportunity to improve operational field worker safety.
- **Reliability:** Improved vegetation management performance could reduce vegetation contact with wires that can cause outages, while improved fuels management could reduce wildfire spread which otherwise can impact reliability when distribution, transmission, or generation assets go offline.
- **Affordability:** New operational efficiencies and/or cost offsets from climate positive biomass conversion improve affordability.
- **Environmental Sustainability:** Through demonstration of relevant technologies there is the potential to improve GHG emissions, criteria pollutants, and ecosystem health outcomes.
- **Equity:** Development of new climate and nature-positive solutions could bring economic development opportunity to low-income, rural portions of PG&E's service area.

Background, Previous Research, and Technology Trends

Climate and nature-positive solutions are emerging and not considered commercially viable, with only a few early-stage projects ongoing or completed with limited work underway with vendors, research organizations, and governmental agencies. Some new technologies utilizing low-value woody biomass as an input are commercially available, though like carbon capture and storage technologies are at an early stage. Substantial questions can include technology selection, capital and operating costs, feedstock supply assurance, project financing, market development, permitting, and details of specific sequestration site selection. PG&E's EPIC 3.47 - *Operational Vegetation Management Through Novel Onsite Equipment* project is conducting preliminary demonstration of technologies and methods for biomass densification and conversion, but it is expected that additional technology demonstration work will be valuable to continue to improve technology options and then to most effectively integrate them into PG&E's operations.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	**Topic Applicable**
Grid Operations/Market Design	●
Generation	●
Transmission	●
Distribution	●
Demand-Side Management	

22. Disaster Protection

Innovation Need

Although PG&E has significant capabilities available to avoid and recover from emergency situations beyond the significant recent investments in wildfire response capabilities, PG&E

continues to face evolving risks such as from earthquakes, volcanic eruptions, and extreme weather, in addition to wildfires. There are new technologies that could help PG&E improve its protection from disasters, to be better able to protect those in its service area, and to be able to recover from emergencies and disasters more quickly and efficiently.

Description

This topic will enable demonstration of a range of disaster protection capabilities, such as:

- Real-time imaging of the entire service territory for improved situational awareness in any time of emergency. This includes the ability to reliably deliver imagery to responding personnel in emergency situations despite adverse conditions. The demonstration would also evaluate the applicability for other use cases, for instance the ability to improve on the speed or accuracy of ignition detections by incorporation of AI analysis of imagery.
- Augmented reality to improve situational awareness for field workers including but not limited to emergency management workers. Use cases include viewing of superimposed diagrams, instructions, and real-time equipment and system condition information by a remote worker by themselves as well as live remote consultation with an experienced operator for both operational and training purposes.
- Enhancements to earthquake protection capabilities, including methods for integrating detection within grid protective devices to trigger automatic de-energization, and other enhancements around real-time data collection and impact modeling. These efforts would leverage the existing State earthquake early warning platform.
- Enhancements to rapid coordination capabilities, damage modeling, delay curves, geo-fencing, and evaluation of impacts after major earthquakes and aftershocks occur using remote sensing technologies.
- Novel drift meter sensors for post-earthquake structural assessment. This is an emerging technology with broad potential use cases to help evaluate the post-earthquake condition related to life safety and operational impacts.

- Validation testing of novel remote sensing technologies such as Interferometric Synthetic Aperture Radar (InSAR) for early ground movement detection on a long-term (year-to-year) basis to identify impacts to utility infrastructure. This addresses multiple hazards and impacts related to earthquakes, storm-induced landslides, subsidence, and flooding.
- New assessment of vulnerability of the electric and gas system to volcanic events/hazard and modeling of impacts to infrastructure, including testing of potentially vulnerable equipment to determine fragility curves to update PG&E's relevant risk models. This addresses potential impacts from active California volcanic zones that are poorly understood at present.
- Advanced modeling of debris flow hazard and sedimentation within watersheds and its effect on operations, including modelling of future effects from climate change that would inform mitigation strategies. This modeling improves worker and public safety awareness, emergency response, and impact mitigation.
- Enhanced communication capabilities on equipment to provide visibility into asset health and rapidly alert field and office workers. This increased visibility into asset and grid health can enable PG&E teams and emergency response teams to react quickly to impacts from extreme weather events.

Expected Outcomes

The expected outcomes from this topic are:

- Improved protection of utility facilities from seismic, volcanic, debris, and wildfire risks
- Improved situational awareness in emergency situations
- Improved emergency response capability
- Improved public safety during and following seismic, volcanic, extreme weather, wildfire, and other risks

Metrics and Performance Indicators

- Accuracy of modeled damage assessments versus actual

- Number of false negative and false positive activations of grid protective devices from monitored events
- Reduction in time to de-energize assets following the start of a seismic event

Primary Users and Beneficiaries

- **Customers** will benefit from the safety and reliability improvements realizable through this topic.
- **IOUs** will benefit from greater protection against environmental hazards and improved capability to recover quickly. Advances in predictive models and emergency response planning can be shared with IOUs leading to better communication, shared response, and consistency.
- **Local governments** will benefit from increased reliability of energy service during disasters, aiding their ability to respond.
- **Technology developers and manufacturers** benefit from having their emerging products evaluated and demonstrated and would be able to improve their products through demonstration experience and utility feedback.
- **Under-resourced communities** are often the most vulnerable to and most impacted by extreme weather events. Disaster protection helps prevent under-resourced communities from facing recovery efforts that are likely to be resource- and time-intensive. Additionally, early communication of potential emergency events can allow communities to prepare and potentially better withstand extreme weather or other emergencies.

Guiding Principles

- **Safety:** A grid is safer when it is better protected from disasters and can recover faster if a disaster does occur. EPIC projects' safety performance will be monitored and reported in PG&E's annual Safety Performance Metrics report (SPM) and biannual Safety and Operational Metrics (SOM) report, as applicable.

- **Reliability:** A more resilient grid that is better protected from disasters will generally suffer lower damage levels and can therefore recover more quickly.
- **Affordability:** The avoidance of damage to PG&E's equipment from disasters will lead to increased affordability.
- **Environmental Sustainability:** The grid is more environmentally sustainable by being able to mitigate the consequences of wildfires through faster detection and from not requiring recovery and re-build after a disaster.

Background, Previous Research, and Technology Trends

Numerous studies have been conducted by many entities on the seismic, volcanic, wildfire, and post-fire debris flow risks, though the application of advancing technologies to adequately address the current and evolving risks lags behind such studies. Systems are currently in place to address such risks and disasters though it is known that they could be improved for the benefit of the public safety, worker safety, and electric system resiliency.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	●
Generation	●
Transmission	●
Distribution	●
Demand-Side Management	

23. Granular Attributes for Environmental Commodity Tracking

Innovation Need

When renewable energy is generated, the environmental attributes associated with that generation are separated from the underlying commodity of electricity. This creates a second tradable commodity called a Renewable Energy Certificate (REC) which represents proof that one megawatt hour of electricity was generated from a renewable resource. This certificate is used as the unit of account for tracking the rights and claims on the associated environmental attributes such as CO_2 reduction.

Since their introduction over 25 years ago, RECs have become a well-established and highly successful instrument for consumers to purchase renewable energy. Since 2004, the consumer market for RECs has grown from 1.6TWh to over 90TWh in 2020. This demand has helped foster development of new renewable energy generation, which in turn has resulted in emission reductions across the electricity system.

Despite this success, RECs remain a blunt and imprecise tool for offsetting emissions from consumer load. One limitation is that RECs are only issued monthly and are not time-stamped. However, the carbon intensity of the grid varies according to the time of day and across seasons. Because RECs do not capture this daily or seasonal variation, customers are unable to match their renewable energy purchasing to their actual load profile.

A second limitation is geography. The carbon intensity of the grid varies by location. In some locations, building new renewable resources merely displaces other renewables. Whereas in other locations, renewable energy can displace the very dirtiest of fossil fuel plants. However, RECs do not include these precise locational attributes to indicate their carbon content. The current practice is to use an aggregated system average across multiple years, and there is opportunity to improve this practice. The introduction of locational attributes would help ensure that local grid carbon displacement is considered and enable companies to better direct procurement to their areas of operation.

Description

The central purpose of this topic is to make electricity traceability more closely represent the physical reality and real-world availability of renewable energy resources. By introducing the time-stamping and precise locational attributes to renewable energy certificates, these "Granular RECs" will more accurately reflect the physical reality of the grid. This topic is designed to develop granular attributes for environmental commodities and evaluate their potential benefits such as:

- Bringing increased transparency to environmental claims
- Better matching clean energy supply with demand
- Enabling more granular carbon accounting methodologies
- Creating an additional price signal for renewable generation
- Displacing fossil generation at specific times and locations to maximize avoided emissions.
- Testing the hypothesis that an increase in flexible and non-daytime renewable generation would lead to the retirement of fossil plants, which are frequently located near rural communities

PG&E is focusing this topic on RECs because it is the most mature market for environmental commodities. However, there are other important environmental commodity markets that could benefit from this demonstration including the Low Carbon Fuel Standard (LCFS) market to support electric vehicle adoption or Renewable Identification Numbers (RINs) to support renewable fuels.

Expected Outcomes

The following outcomes are expected to result from this topic:

- A framework to issue and track Granular RECs on an hourly basis
- Application of this framework to a tracking platform which enables customers to match Granular REC procurement to their hourly load profile
- Demonstration of the integrity of environmental claims through auditing the chain-of-custody in accordance with existing standards
- Analysis of the effectiveness of Granular RECs to incentivize renewable generation during times of highest carbon intensity when it is needed most

- Testing of the hypothesis that an increase in flexible and non-daytime renewable generation would lead to the retirement of fossil plants, which are frequently located near rural communities

Metrics and Performance Indicators

- Number of participants in a Granular REC marketplace
- Incremental avoided emissions of Granular RECs over standard RECs

Primary Users and Beneficiaries

- **Customers** would benefit from accurate, granular, and timely information that would improve consumer choice regarding the origin and time of specific energy generation. Additionally, this topic is designed to support the 24/7 carbon free energy goals adopted by PG&E customers.
- **Regulators and planners** would benefit from understanding emissions profiles at specific times and locations on our grid to enact more targeted policies. Regulators would also benefit from increased fidelity of GHG emission reporting and key performance indicators (KPIs).
- **Renewable Generators** would benefit through increased incentives to export into the grid at times of high carbon intensity. Granular RECs could open market opportunities for small, distributed energy generators who would otherwise have limited access.

Guiding Principles

- **Affordability:** This topic would improve customer choice so they can identify opportunities to meet their emissions commitments in the most cost-effective way possible.
- **Environmental Sustainability:** This topic allows customers to favor options that economically improve their environmental profile.
- **Equity:** This topic would enable a solution that would accelerate usage of emissions-free energy in areas where it displaces the most carbon, typically in rural, disadvantaged or low-income communities.

Background, Previous Research, and Technology Trends

The state-of-the-art for RECs is built on technology and processes developed in the early 2000s:

- RECs are issued and tracked over tracking systems which issue RECs on a monthly basis with a 3–6-month delay between energy generation and physical settlement. This topic does not seek to displace existing tracking systems but rather be a companion to provide customers more granular data on the RECs settled over these systems.
- The carbon value of RECs is currently calculated using EPA's eGrid Data which measures emissions by region and is updated every 2-3 years. Currently the carbon value of RECs is calculated with emissions data from February 2021.
- CAISO tracks hourly emissions for their Balancing Authority Area but this information is not integrated in REC emissions tracking. CAISO's methodology does not use the marginal emissions approach which may be more appropriate for RECs.

The building blocks required to realize this topic's expected outcomes are maturing but there have been limited projects and companies combining these building blocks in ways that are also consumer-facing.

A Granular REC Standard was released in March of 2022. This new standard is supported by one of the largest compliance tracking systems in the country, by PG&E's peers, and by large corporate purchasers of renewable energy.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	●
Generation	●
Transmission	
Distribution	
Demand-Side Management	

CHAPTER 5: Administration and Governance of PG&E's EPIC Investment Plan

Collaboration with Program Administrators and Stakeholders

The CPUC's EPIC decisions require the four program Administrators to file coordinated Investment Plans. Throughout the execution of its EPIC 3 investment plan and in the development of its EPIC 4 Investment Plan, PG&E has worked collaboratively with the other three Administrators. This collaboration has included conducting conference calls, participating in each other's public workshops, and coordinating a number of in-person or phone-based joint portfolio review meetings. These efforts have been designed to coordinate Investment Plans and ensure investments were complementary and not unnecessarily duplicative.

Together, the Administrators have identified topics where more technical coordinated efforts from all the Administrators is warranted and plan to continue to share information and coordinate efforts in these areas to maximize benefits for all California customers of the IOUs. Areas of coordination will include, among others, RD&D activities related to:

- Distributed energy resources
- Long range planning
- Interconnection
- Microgrids
- New generation
- Transportation electrification

In the EPIC 4 cycle, the Administrators propose to take existing collaboration a step further by potentially executing joint projects in a number of areas as identified in the topic narratives in Chapters 2–4 above. Now that the IOUs have been given the flexibility to file their investment plans at the broader topic level instead of the detailed project level, this gives the Administrators more flexibility to align their funds and implement joint projects over the course of the EPIC 4 cycle.

The EPIC Administrators will continue to work together to address common goals, consistent with the state's energy and environmental policies and the EPIC program's updated guiding as established in D.21-11-028.[28] EPIC Administrators will also continue to coordinate scheduling, solicitation, and responses to comments and advice from stakeholders on their respective proposed and ongoing RD&D plans and programs. To this end, the EPIC Administrators will continue to share information regarding this EPIC 4 Investment Plan, as well as the EPIC 1, 2 and 3 portfolios. As projects complete, the Administrators will continue to meet to discuss project learnings and facilitate the dissemination of the results of the program efforts for the benefit of all California customers.

Furthermore, PG&E shares knowledge gained, and lessons learned with the industry through presentations or papers at conferences or electric groups/committees, such as DistribuTECH, Institute of Electrical and Electronics Engineers (IEEE), and Edison Electric Institute.

To the extent permissible, the EPIC Administrators will work together to avoid unnecessary duplication of efforts, consistent with Public Utilities Code 740.1 and 8360-8369, and to leverage the EPIC funding for the benefit of all electric utility customers. Frequent discussions among the EPIC Administrators will help to avoid duplication, identify potential projects, and facilitate knowledge sharing. Furthermore, when developing topics for this EPIC 4 plan, PG&E evaluated technology projects included in its other regulatory filings to avoid unnecessary duplication.

Treatment of Intellectual Property

PG&E will continue to administer and protect intellectual property rights in accordance with the guidelines provided in the Commission's EPIC decisions.[29]

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28. D.21-11-028, Appendix A.
29. D.13-11-025, at OP32, OP 34, and OP 50.

Project Portfolio Governance Process to Leverage EPIC Investments

Given the dynamic nature of RD&D efforts and the rapidly evolving electric industry, PG&E will continue to evolve the portfolio, as well as use project and program governance processes to identify, evaluate, select, and prioritize projects in an efficient manner.

Specifically, upon approval of its EPIC 4 Investment Plan, PG&E will employ the following process:

- Develop an objective set of criteria for scoring and prioritizing candidate projects
- Work internally to derive specific project opportunities from the higher-level set of topics in its EPIC 4 application
- Flesh out the preliminary details of candidate projects in a standardized template
- Socialize candidate projects with the other administrators, ensure non-duplication among administrators' planned efforts, and in some cases align candidate projects with counterpart projects of the other administrators
- Present candidate projects to an internal leadership committee that will score them using the established scoring criteria
- Present the resultant subset of candidate projects to the public for feedback and use that feedback to update project scope and inform the relative priority among projects. Also engage with DACs and other communities through PG&E's equity team, PG&E's Community Perspectives Advisory Council (C-PAC), and other channels to incorporate broader community feedback and identify opportunities to partner with communities to host projects that will have field demonstration components.
    - In 2022, as part of PG&E's effort to expand and deepen its CBO partnerships, and engage CBOs across the service territory to assist in reaching customers and providing households education and outreach, PG&E created a new Community Perspectives Advisory Council. C-PAC intends to increase the diversity of CBO perspectives that we are consulting with in our programs, and while the topics

for the Council are wide ranging, they are focused on customer and emerging technology programs and projects. Through engagement with C-PAC, PG&E can engage in conversations about potential EPIC projects and how best to communicate technical information to a wide range of public stakeholders. Additionally, C-PAC members share our public EPIC workshop invitations with their memberships base. This feedback and outreach can support increasing DVC and CBO participation in EPIC Workshops.

- Make final project selections, develop detailed business plans, obtain leadership approval of business plans, release funds, and launch projects.

As a result of this process, PG&E will have launched projects related to numerous topics included in its investment plan application. For some topics, multiple projects may be pursued, whereas for other topics PG&E may not ultimately pursue any projects depending on evolving priorities as well as budget and internal resource limitations. While PG&E will work through the process outlined above to launch a large set of initial projects upon approval of its EPIC 4 plan, it may hold budget in reserve and plan to launch subsequent waves of projects further into the investment cycle. Once projects are launched, PG&E will implement a wide range of governance functions to ensure project success and comply with regulatory requirements throughout the project lifecycle. These functions are further described in the Joint EPIC Administrative Framework[30] filed by the Administrators in January of 2022.

In selecting and allocating budget to individual projects, as required by D.21-11-028,[31] PG&E will manage to the budget allocations it has established at the overarching initiative level. If PG&E anticipates a need to re-allocate more than 15 percent of total program funds among its initiatives, it will first file a Tier 2 Advice Letter and obtain CPUC approval before doing so.

30. PG&E Advice 6487-E, Joint EPIC Administrator Advice Letter Proposal of Eligible Administrative Budget Line items.

31. D.21-11-028, OP 8.

While PG&E employed a very rigorous process to define the broad set of 23 topics in its EPIC 4 application, over the course of the cycle additional needs and opportunities may arise that were unforeseen at the time investment plan development. As such, PG&E requests that the CPUC allow the IOUs to file Tier 3 Advice Letters to request approval to add any additional topics to their plans, after their plans are approved. This would be analogous to the previous process for requesting approval to pursue additional projects when investment plans had been filed at the project level.

In addition, and consistent with the Commission's treatment of the IOUs' EPIC 3 programs in D.18-10-052[32], PG&E requests that the IOUs be authorized to fund their EPIC 4 projects for a full five years from the effective date of the decision approving their plans, rather than only through the end of 2025. This will allow for more effective sequencing of projects to allow for progressive maturation of technologies and solutions that would otherwise be limited if the IOUs were only authorized to fund projects between expected CPUC approval in the first half of 2023 and the end of 2025.

Program Budget

D.21-11-028 established each administrator's EPIC 4 program budget[33]. PG&E's budget from the decision is included below in Table 4.

Table 4: PG&E 2021-2025 Budget

32. D.18-10-052, OP 7.
33. D.21-11-028, Appendix B.

Total EPIC Budget	$925,000,000	
Total CPUC Oversight Budget	0.5% of total EPIC Budget	0.5 * $925,000,000 = **$4,625,000**
IOUs' Portion of Total EPIC Budget	20% of total EPIC Budget	0.2 * $925,000,000 = **$185,000,000**
PG&E Collection Allocation	50.1%	
PG&E EPIC Budget	50.1% of IOU share of EPIC budget	0.501 * $185,000,000 = **$92,685,000**
PG&E Administrative Budget	10% of PG&E EPIC Budget	0.1 * $92,685,000 = **$9,268,500**
PG&E Share of Oversight Budget	10.02% of total CPUC oversight budget (50.1% of remaining 20% not paid by CEC)	0.1002 * $4,625,000 = **$463,425**
PG&E Program Area (TD&D) Budget	(PG&E EPIC Budget) – (administrative and oversight budgets)	$92,685,000 - $9,268,500 - $463,425 = **$82,953,075**

As noted above in Chapter 1, PG&E does not have uncommitted EPIC 3 program funds with which to offset its EPIC 4 program budget. PG&E will administer its EPIC 4 program within a 10 percent administrative budget cap, in conducting the administrative activities described in the CPUC-approved Joint EPIC Administrative Framework. PG&E will also remit its collected portions of the CEC program budget and the CPUC oversight budget in accordance with the requirements established in previous EPIC decisions.

EPIC 4-Related Costs Incurred to Date

In complying with D.21-11-028, PG&E has incurred costs in conducting the following activities:

- Coordinating with its fellow administrators and the CPUC to develop a joint administrative cost framework, facilitating a public workshop on this framework, and finalizing and filing this framework (Ordering Paragraph 16)
- Developing its EPIC 4 Investment Plan and Application (Ordering Paragraph 7)
- Coordinating with its fellow administrators and the CEC to develop a common framework for benefits reporting, and developing and filing its corresponding EPIC 1, 2, & 3 Benefits Impact Report ((Ordering Paragraphs 12 & 13)

While D.21-11-028 determined that the "IOU Administrators will need to be reimbursed for the administrative costs incurred in preparing the benefits report in Ordering Paragraph 13 and thus the Commission should authorize the reimbursement using EPIC funds."[34] PG&E respectfully requests that the IOUs be authorized to account for the costs incurred in complying with all of the above ordered activities through its authorized EPIC 4 budget. PG&E has tracked the expenditures associated with these activities, and the expenditures through August 2022 are $200,155, with additional expenditures incurred but not yet available for reporting for September of 2022.

Procedures for Competitive Solicitation of Projects and Outreach to Stakeholders and Third Parties

Upon approval of its EPIC 4 application, PG&E intends to continue to consult regularly with other interested stakeholders and subject matter experts as part of the execution of the EPIC 4 Investment Plan. Beyond workshops and other stakeholder engagements, PG&E continues to maintain its own EPIC website,[35] and has contributed to the establishment of the joint EPIC database[36] and website to inform interested parties of PG&E's EPIC portfolio. PG&E also continues to post announcements on its broader sourcing website[37] when bidding opportunities arise for specific projects.

PG&E's selection of new strategy and/or technology partners or vendors for individual projects will continue to employ a public competitive solicitation process as the preferred and default acquisition method, in order to draw upon a broad array of external expertise and innovation. Eligibility criteria for award of TD&D funds will be determined on a project-by-project basis and

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34. D.21-11-028, Conclusions of Law paragraph 4.
35. https://www.pge.com/epic.
36. https://www.epicpartnership.org.
37. https://www.pge.com/en_US/for-our-business-partners/purchasing-program/bid-opportunities/bid-opportunities.page?WT.mc_id=Vanity_bidopportunities&ctx=large-business.

PG&E will generally follow the IOU Contractor Solicitation Process and Evaluation Guidelines adopted in D.13-11-025.[38] Where a unique or specific expertise or capability is identified for an individual project, PG&E may employ sole source procurement procedures following PG&E's established procurement processes.

PG&E does not expect to use grants or loan-type contracts for EPIC projects but does not rule them out. PG&E may include "performance-based" incentives or requirements in its contracts, such as demonstrating a minimum level of operating experience and performance when demonstrating a particular technology, facility, or process in the field. As is usual for utility contracts in general, PG&E's EPIC contracts will retain audit rights for both PG&E and the CPUC.

38. D.13-11-025, Attachment 3.

CHAPTER 6: Benefits Metrics & Evaluation of PG&E's EPIC 4 Investment Plan

PG&E expects to use a combination of quantitative metrics and qualitative criteria in evaluating the potential benefits and actual results of its EPIC-funded projects. In accordance with D.21-11-028[39], PG&E has coordinated with CPUC staff and its fellow program Administrators to develop a uniform benefits analysis framework to enable the evaluation and tracking of the benefits of all EPIC projects. This framework was used as the basis for the EPIC 1, 2, & 3 Benefits Impact Report included as Appendix C of this application, and PG&E will leverage this framework going forward to both evaluate the potential benefits and quantify the realized benefits of its EPIC 4 projects.

As PG&E works to select EPIC 4 projects and develops detailed business plans for its projects, it will define the applicable sets of benefits metrics from the benefits analysis framework, define approaches for calculating each metric, conduct preliminary forward-looking estimates of potential benefits, and define plans for capturing data over the course of the demonstrations that will be needed to perform updated calculations of both realized and potential future benefits as projects near completion. PG&E has committed to quantifying, as applicable, and publicly sharing the benefits of its projects upon completion in each project's final report. PG&E will begin to provide this information for its EPIC 3 projects, as they start to close later in 2022, and for its EPIC 4 projects going forward. The benefits metrics provided in projects' final reports will also be included in the newly established joint EPIC database.

39. D.13-11-025, OP12.

CHAPTER 7: Conclusion and Next Steps

The five Initiatives in PG&E's EPIC 4 Investment Plan will be key to PG&E's ability to realize the safe, affordable, reliable, environmentally sustainable, and equitable electric grid that Californians need and deserve.

PG&E will continue to be a leader of grid innovation and improvement to the electric system as we continue the transition to a zero-carbon system that is resilient and reliable in the face of climate change, and as we continue to provide electric service that is safer every day for our hometowns. Throughout PG&E's EPIC 4 Investment Plan, PG&E has detailed initiatives and topics that will support Commission proceedings and help ensure that California achieves its environmental and energy system goals. PG&E has also addressed equity throughout the topics in its proposed EPIC 4 Investment Plan and will continue to pursue opportunities to enhance equity in our work. PG&E values the input received from the two public and two DAC-specific workshops. This extensive stakeholder engagement informed the Strategic Objectives, Initiatives, and Topics proposed within this EPIC 4 Investment Plan.

PG&E anticipates that the Commission will begin reviewing the IOUs' respective EPIC 4 Investment Plans to consider approval during the fourth quarter of 2022 and issue a final decision in the first quarter of 2023. Upon the Commission's approval of PG&E's EPIC 4 Investment Plan, PG&E will begin a rigorous process of internal planning and external coordination, including public workshops, to define its first wave of projects. PG&E looks forward to continued collaboration with the Commission, the CEC, SCE, SDG&E, and other EPIC stakeholders to align and launch sets of projects to advance the electric grid and deliver on the guiding principles of the EPIC program for the benefit of all Californians.

APPENDIX A: Summary of Stakeholder Feedback

Overview

As mentioned in Chapter 1 of PG&E's EPIC 4 Investment Plan Application, public stakeholder workshops are required at least twice per year, during the development of the Administrators' respective investment plans and during the execution of those plans. The purpose of these workshops is to contribute to ongoing coordination and understanding among administrators, external stakeholders, interested parties, and the California Public Utilities Commission (CPUC), while also raising awareness and visibility of Electric Program Investment Charge (EPIC) investments and promoting EPIC program transparency. Interested stakeholders may include: California legislature, State and Federal government agencies, utilities, California Independent System Operator (CAISO), consumer groups, environmental organizations, agricultural organizations, academic experts, industry research consortia, technology accelerators, business community, energy efficiency (EE) community, and clean energy or other industry associations.

The general themes of the stakeholder comments received during public workshops focused on general EPIC-related information, and on Utility technology gaps and demonstration priorities. Workshop slide presentations are available on PG&E's EPIC web page[40]. In addition to workshop materials, PG&E's prior EPIC Investment Plans, PG&E's EPIC Annual Reports, as well as links to the other Administrators' EPIC information, can be found there. PG&E's answers to main stakeholder inquiries made in the four workshops are in Table A-1 to A-4 below. These tables capture feedback, questions, or comments directed to PG&E specifically.

Table A-1: PG&E Responses at Joint Utilities EPIC DAC Workshop, June 21, 2022

Stakeholder	**Feedback/Question/Comment**	**PG&E Response**

- 40. https://www.pge.com/epic.

DAC Workshop Participant	Question regarding the “System Harmonics for Power Quality Investigations” topic: Are the smart meters used for the demonstration the standard meters or are they retrofitted in their hardware or software?	The smart meters used for this demonstration are a newer, more capable version of the current generation smart meters. These newer smart meters can sense, record, and communicate grid conditions with high accuracy and in the small intervals needed for these harmonics investigations.

Table A-2: PG&E Responses at the Joint Utilities EPIC Public Workshop, June 30, 2022

Stakeholder	**Feedback/Question/Comment**	**PG&E Response**
Industry Research Consortium Representative	Question regarding the “Remote Grid and Microgrid Enablement” topic: Might the research in this topic address the relatively high cost of microgrid deployment, beyond standardization of designs?	Yes. As noted, one expected outcome of this topic is a reduction in cost from the standardization of designs. Part of this topic is to investigate in what other ways that microgrid deployment can be simplified, as that can help speed interconnection and streamline completion (thereby lowering costs) for all parties.
Industry Research Consortium Representative	Question regarding the “Individual Customer Resiliency” topic: Might the include research into utility programs for front-of-the-meter assets?	Yes, the topic anticipates that a range of solutions on either side of the meter could be demonstrated, to fit the varying use cases. The Microgrid Enablement topic will also explore FTM assets for resiliency.

Industry Research Consortium Representative	Question regarding the "Long Duration Energy Storage" topic: How much work will be done in determining exactly how much long-duration storage is necessary and what the duration should be? Will there be work into assessing how long-duration needs (especially for contingencies) might be satisfied with a portfolio of short-duration assets?	Broader studies to determine how much long duration storage is necessary will be done outside EPIC, and by themselves are not appropriate as Utility TD&D EPIC projects. The demonstration of LDES technologies will help to shed light on the performance and applications of specific LDES technologies compared to specific SDES technologies.
Academia Representative	Question regarding the "Grid Scenario Planning" topic: "For those utilities such as PG&E and SCE who [operate] the non-electric infrastructure have you looked at interdependencies between non-electric and electric [infrastructure]?"	Generally speaking, yes, this is a central issue for PG&E. Also, PG&E's Grid Scenario Planning topic will develop capabilities that allow for simulating and developing strategies to address building electrification broadly, as well as zonal electrification of the gas system.
CPUC	Question regarding the "Data Analytics for Predictive Maintenance" topic: Are the data analytics in this topic related to machine learning?	Yes, the predictive analytic diagnostics rely on machine learning.

Table A-3: PG&E Responses at Joint Utilities DAC Workshop, August 25, 2022

Stakeholder	Feedback/Question/Comment	PG&E Response

DAC Representative	Question regarding the buyback of second-life electric vehicle batteries and analysis of the number of EVs, and therefore the applicability of battery buy-backs to, low-income electric vehicle owners, as electric vehicle ownership tends to cluster in higher income brackets.	The viability of deploying second-life battery energy storage systems in locations that benefit disadvantaged communities specifically will be explored. There would also be an exploration of whether there are opportunities for second-life battery energy storage system vendors to coordinate the procurement of the batteries needed for the demonstrations from these same communities, acknowledging that there may be less opportunities for this part. The communities could nonetheless be informed of a buyback option, as it can aid electric vehicle adoption if it is known that a second-life buybacks could lower the total lifetime cost of ownership of the electric vehicle.
City Representative	Comment related to the "Electric Vehicle Charging and Integration Enablement" topic and the "EV Battery Re-Use for Stationary Energy Storage" topic: We have a fleet of heavy-duty transit buses that are battery powered and in secondary life. It's exciting to see the advancement and wide range of	We expect to consider for demonstration a broad range of EV technology and solutions, including alternative charging technologies such as wireless charging, as well as battery swapping, as is described in PG&E's "Electric Vehicle Charging and Integration Enablement" topic.

	topics discussed for EPIC 4. One area for future consideration that is maybe an expansion of what's already been discussed today is the opportunity for battery swapping as it has a lot of purposes within it.	
DAC Representative	Comment: For EV-related topics, since DACs might not have high penetration of EVs that would be needed as the basis to conduct the demonstrations, look for opportunities to align EPIC funds with resources from other customer programs and Federal funding opportunities to provide communities with the EVs.	PG&E will look for such opportunities. This has been incorporated into the Equity section of PG&E's "Electric Vehicle Charging and Integration Enablement" topic.
DAC Representative	Comment: To be successful in working in DACs it is important to have partners that know and work in the area. Therefore, the importance of working with CBOs and developing some partners as projects are rolled out.	PG&E has formed the Community Perspectives Advisory Council (C-PAC) to strengthen communication with representatives of community-based organizations representing DACs as well as underserved, and vulnerable communities. As described in Chapter 5 of this investment plan, after PG&E's EPIC 4 Investment Plan is approved, for individual projects that are identified as good candidates for DAC partnership, PG&E would work through the C-PAC and community

		representatives to explore these opportunities, inform project plans, form partnerships.

Table A-4: PG&E Responses at Joint Utilities EPIC Public Workshop, August 29, 2022

Stakeholder	Feedback/Question/Comment	PG&E Response
CEC	Question about preference for laboratory vs. field demonstrations for Utility EPIC projects	When practical, field demonstrations are preferred over laboratory testing. It is dependent upon the specific situation, and often project work starts with planning followed by limited laboratory testing that then proceeds to a field demonstration. Field demonstrations are often located at existing PG&E facilities and therefore are not necessarily apparent to customers. Analytics projects often use live utility data so although they are unseen they are nonetheless field demonstrations.
CEC	Question about what budget allocations utilities have preliminarily set at the initiative level	PG&E has not set allocations at this time and will do so when the investment plan is filed on October 3, 2022.
CEC	Question about topic non-duplication and collaboration process after utility investment plans are filed	PG&E has extensively collaborated with the CEC, SCE, and SDG&E to coordinate on topics, ensure effective information sharing, avoid duplication

		of effort, and to identify synergistic opportunities for conducting projects together. Furthermore, PG&E expects that this coordination and collaboration process will continue and extend to the discussion of individual projects of each of the four Administrators after the IOUs' investment plans are filed. Specific areas initially targeted for collaboration include microgrids, long duration energy storage, and transportation electrification.
CPUC	Question regarding utility laboratories, interoperability testing, standards participation and development, and the role of the utilities	PG&E will conduct work in these areas consistent with its role. PG&E actively participates in many standardization processes, sometimes leading those efforts. PG&E and the other IOUs are in a unique position to be able to conduct interoperability testing of a wide variety of grid equipment in real-world and near-real-world operational environments. The feedback provided to the equipment vendors from these efforts helps improve the products for the benefit of all.
Academia	Question around whether the utilities have thought of establishing a utility-owned communication	PG&E developed an IEEE-compliant head-end system as part of its EPIC 3.03 DERMS project, which has

	platform for DER owners and whether it is covered in the proposed topics	enabled owners of large DERs to provide telemetry data to PG&E at low cost. PG&E will further explore enhancements to this platform, including the ability to send DERs control signals, through its "Advanced Distribution Powerflow Management" topic.
CEC	Question around whether the utilities will be pursuing any specific technologies for grid hardening and remediation.	Yes, PG&E will be addressing this through its Climate and Environment initiative, particularly its "Undergrounding Capabilities" topic, and other topics such as "Preventing Faults from Causing Ignitions" to a lesser extent"
CPUC	Question regarding the "Pinpointing Fault Location" topic: What is the innovation need? Can't the existing systems just be expanded? and the need, and what the ideas are for improving.	The innovation need over the present systems is to: 1) improve the accuracy of the detected location of the fault, for instance on both overhead and underground conductors; 2) cost-effectively deploy such systems beyond the presently limited areas; and 3) identify faults in more types of grid equipment, such as in power transformers.

APPENDIX B: Information Summary of Demand Response (DR) Research, Development and Demonstration (RD&D) Activities

The Electric Program Investment Charge (EPIC) Decision (D.) 13-11-025 requires informational summaries of the IOUs' Research, Development and Demonstration (RD&D) activities undertaken as part of their approved Energy Efficiency (EE) and Demand Response (DR) portfolios. Pacific Gas and Electric Company's (PG&E) understanding is that the California Public Utilities Commission (CPUC) requests this information to confirm non-duplication of efforts.

PG&E's EE, DR, and EPIC Programs Are Distinct Programs with Separate Objectives

PG&E established its EE Program in 1976 and its DR Program in 1959. Each program has a distinct program focus, which is described in further detail below and is separate from EPIC's focus. Both the EE and DR programs provide program updates to the CPUC on the progress of these projects through either written reports or in person meetings. A summary of RD&D-type activities, including the purpose, funding, deliverables and progress to date, has been provided below in Tables B-2, B-3 and B-4, including PG&E's EE-Emerging Technology Program (ETP) projects, the joint Statewide EE-ETP projects, and the DR Emerging Technology (DRET) projects, respectively. The EE, DR and EPIC program owners have developed program guidelines to delineate the differing focus areas, which is provided in Table B-1.

Summary of EE and DR RD&D–Type Activities

PG&E's EE Portfolio is part of California's statewide initiative to achieve the state's EE goals by providing EE products, services and process improvements to end customers, through the use of rebates and incentives, energy analyses, and workforce training and education. Activities in the Energy Efficiency–Emerging Technology Program (EE-ETP) are not generally considered "RD&D," as they are focused on assessing, demonstrating, and deploying commercially deployed technologies. This approach differs from the focus for EPIC which targets demonstrations for pre-commercial technologies. The EE-ETP facilitates customer adoption of commercially available new and underutilized EE technologies, practices, and tools. The program is designed to help California customer -funded EE programs meet the state's energy reduction needs by identifying cost--effective measures that deliver reliable energy savings.

In general, the distinction PG&E makes between EE-ETP and EPIC programs is that EE-ETP's focuses on customer-side EE technologies and individual customer adoption via incentives, whereas the Utility's EPIC program covers non-EE initiatives and/or initiatives that incorporate/integrate EE, as well as other types of demand management (e.g., Integrated Distributed Energy Resources). The market facilitation of new technologies, a component of EE-ETP, is explicitly disallowed in EPIC for the IOUs, thereby further delineating Utility EE and EPIC programs. Finally, while EE-ETP is for both electric and gas applications, the Utility EPIC program is for electric Technology Demonstration and Deployment (TD&D) only.

PG&E's Demand Response Emerging Technology (DRET) Program is part of California's statewide program, which provides an opportunity for customers to play a significant role in the operation of the grid by changing their electricity consumption during peak periods in response to either economic or reliability signals. PG&E's DRET Program explores new technologies and applications that have the potential to enable or enhance DR capabilities and can include hardware, software, design tools, strategies, and services. The EPIC program avoids DR-only technology demonstrations, and instead focuses on integrating multiple Distributed Energy Resources (DERs), such as solar, behind-the-meter (BTM) storage, electric vehicles (EV), and potentially DR (or EE) as a resource.

In order to further delineate the focus of each program, Table B-1 summarizes the differences and similarities of the EE-ETP, DRET, and EPIC programs described above.

Table B-1: Comparison of EE-ETP, DRET, and EPIC Programs

Program Considerations	**EE-ETP**	**DRET**	**EPIC**
Does the program demonstrate grid optimization technologies or customer side technologies?	Customer Side	Customer Side	Both
Does the program demonstrate pre- commercial/not yet widely commercialized or commercialized technologies?	Not yet widely commercialized & commercially available	Commercially available	Pre-commercial or not yet widely commercialized
Does the program support electric or gas applications?	Electric & Gas	Electric only	Electric only
Does the program have a demand side focus or grid integration focus?	Demand-Side	Both (demand side for ultimate grid integration)	Both
Does the program focus on the site specific net effect on load or aggregated effect on load?	Site Specific	Both	Aggregated
What aspect of technologies does the program evaluate?	Energy savings & peak demand performance verification	Depends on assessment; Often load impact	Broad Range (Stronger focus on demonstration)
Does the program evaluate the existing program and process?	No	Sometimes	Sometimes
Does the program assess the technology capability of peak load reduction or load shifting?	Load reduction	Both	Both

Does the program have a focus of market facilitation of commercially available technologies?	Yes	Yes	No

Tables B-2 and B-3 list the activities in PG&E's EE-ETP portfolio and the Statewide EE-ETP portfolio respectively. These tables include each project's description/purpose, funding, deliverables, and progress to date. Table B-4 summarizes the DRET projects which include the projects' description/purpose, funding, deliverables, and progress to date.

Table B-2: PG&E EE-ETP Projects

Project Start Year	Project Name	Purpose	Funding	Deliverables	Progress to Date
2017	APS2 Online Limited-Time-Offer ET Assessment	The project will assess the effectiveness of a downstream, self-install approach by selling 1,000 devices to interested customers, who will be surveyed to understand install and persistence rate.	$150,000	ET Report	Completed
2017	Agricultural-Industrial Controls Market Study	Review of market adoption of VSD/Control systems for possible expansion of product offering and re-write of Work Paper.	$7,500	WP Updates	Completed
2017	Airflow Management for Data Centers	Allowing cost-effective implementation of air management in small data centers is important since the vast majority of the remaining potential for savings in data centers is in small centers. We will test air management packages in live data centers to refine the packages and the energy	$125,000	N/A	Cancelled

		modeling estimates from a 2016 PG&E study. LBNL will standardize the packages for large-scale deployment to allow deemed savings. The deliverables will include descriptions of the improved packages and a detailed implementation roadmap.			
2017	Water AMI Pilot	The effort was mandated by CPUC as part of Water/Energy Nexus; CPUC approved the scope of the project in D.16-06-010 on June 9, 2016. The project seeks to assess the value of providing customers with near real-time granular water use reporting as a means of determining how behavior and technology-based water interventions can reduce water usage, peak energy usage, and total energy usage. For the purpose of this study, PG&E and its partners, East Bay Municipal Utility District and UC Davis, will use customer meter data (at the highest	$400,000	ET Report	Completed

		resolution available) for residential electricity, gas, and water consumption, as well as targeted water and energy conservation messaging.			
2017	Energy Management Circuit Breakers - EPRI	Eaton has recently developed a new type of circuit-breaker, the Energy Management Circuit Breaker (EMCB), that fits into a standard electrical sub-panel with embedded data monitoring and ability to remotely turn the breaker on or off. After running a lab test of the circuit-breaker, EPRI is using customer field deployments to gain further understanding of the technical and market potential of the circuit breaker, in collaboration with 12 other utilities with each utility defining their own scope, use case, and learnings.	$375,000	N/A	Cancelled

		The EMCB is potentially an integrated, turnkey solution for circuit-level monitoring that needs validation as a measurement and monitoring device.			
2017	Connected Home Market and Technical Characterization Study	The project will conduct a state of the industry study of the stacked effect? in the Connected Home space, with the goal being to have a deeper understanding of the market players and value when optimized energy consumption is provided, or not provided, to residential households.	$75,000	ET Report	Completed

2018	Connected Restaurant EMS	SMB customers are high EUI establishments who often dont understand where their energy consumption comes from and thus do not have the tools to reduce their energy use. Gridpoints Building Management Systems (BMS) technology includes sub-system controls and data analytics to provide the tools necessary for such establishments to understand and reduce their energy consumption. This project will test the energy savings potential of a the SiteSage BMS technology at a one specific SMB customer site.	$200,000	ET Report	Completed
2018	HVAC Monitoring and Controls for SMB	To Be Determined	$450,000	N/A	Cancelled
2018	Connected Home Product Bundle Field Study	The study will assess the technical and customer satisfaction aspects of bundles including smart thermostats, lights, switches, and other devices.	$300,000	ET Report	Completed

2018	Development of a Laboratory Data-Based Algorithm for Horizontal Drain Water Heat Recovery Devices, and Predictions of In-Field Performance	This project evaluated H-DWHR performance and practical issues through laboratory testing of three HDWHR devices, algorithm development, and simulation studies.	$0	ET Report	Completed
2020	Sensor Based Range Hoods	The project objective is to investigate the technical and market feasibility (including consumer acceptance) of different sensor-based range hoods, with the goal of using results to inform Title 24-2025 code change proposals and other programs supported by PG&E that could benefit from an understanding of how range hoods play a role in improving indoor air quality, especially in smaller dwelling spaces. Goals include: 1) Identify existing and emerging products that use or could be adapted with integrated sensors,	$372,770	ET Report	Completed

		including after-market products for automated control of kitchen range hoods that exhaust to outdoors; 2) Assess energy and indoor air quality (IAQ) performance, economics, adoption feasibility and consumer acceptability of these products; and 3) Recommend solutions that could be included in 2025 Title 24, Part 6 code change proposals and future utility work papers			
2021	Thin-Glass Triple-Pane (TGTP) Windows Tech Intro Support	Evaluate the market-readiness, through production home builder demonstrations in climate zones 11, 12, or 13 with a limited number of incentivized homes per project, of triple-pane windows with a thin center pane of glass (≤ 2mm thick), fitting into a typical double-pane window frame with an NFRC-rated U-factor ≤ 0.22 and SHGC that will comply with the Energy Code. This project tests for	$485,000	Report	Completed

		procurement challenges, cost, and installation issues.			
2021	Climate Wizard 3 (CW3) Modeling and Insulated Duct Analysis	The CW3 is a cooling system which provides 100 percent outdoor air. Since the system relies solely on evaporating water to produce cooling, there is no compressor energy use or associated refrigerant, which allows the system to achieve very high efficiencies. This project evaluates the CW3 for both residential and classroom applications and compliments the CVRH project.	$195,408	ET Report	Completed

2021	Central Valley Research Homes (CVRH)	The CVRH project converted four existing single-family buildings in Stockton, California into unoccupied laboratory houses to study residential energy saving opportunities. Current focuses include testing the performance of VCHPs (mini-split heat pumps) at two, one is evaluating a Sanden HPWH (for space heating and hot water) and a CW3, and the fourth focuses on air-to-water heat pump performance, coupled with radiant ceiling panels, hydronic fan coils, and thermal energy storage.	$2,093,990	Expected ET Report	In process
2021	Midstream Heat Pump Water Heater (HPWH)	The project will test various strategies to engage midstream market actors and conduct an assessment to accelerate the adoption of connected unitary heat pump water heaters with controls for load-shifting for retrofit applications. Data collected will	$1,000,000	Expected ET Report	In process

		include panel upgrade needs, cost, labor information and DR aspects. This project is supported by PG&E's EE and DR Programs and will build upon the knowledge gained during prior HPWH studies.			
2021	Controlled Environment Horticulture Tech Evaluation	Investigate the energy reduction potential of lighting and controls systems that integrate HVAC with other energy end uses for CEH facilities;	$450,000	Expected ET Report	In process
2021	Villara Three-Function Heat Pump	Investigate Energy Savings Potential of three function HP system for Residential Heating, Cooling and Hot Water	$175,000	Expected ET Report	In process
2021	Induction Cooktop Loaner Program	To help support introduction of Induction Cooktops to both Residential and Commercial Market Segments. To help identify obstacles to adoption by allow customers to "try it before you buy it" Includes technical support to commercial	$257,000	Expected ET Report	In process

		food service customers utilizing the Food Service Technology Center			
2021	Advanced Water Heating Initiative and Grid Optimal Support	To Transform Residential Water heating market to HP Technology by creating demand through awareness and incentives directed at multiple points through supply channel. (Direct to customer, Dealer & retailer incentives). Project also includes placement of brand new 120v HP water heater designs intended to overcome existing home panel capacity issues. Project also includes TOU research to ensure added electric load is minimized at peak demand periods	$509,990	Expected ET Report	In process
2021	Intertek Portable Battery Testing	Conduct Performance Testing on residential battery systems	$200,000	Expected ET Report	In process
2021	XeroHome/Vistar	Existing Home Energy Modeling in in SLO and Petaluma	$466,000	Expected ET Report	In process

Table B-3: Statewide EE ETP Projects

Project Start Year	Project Name	Purpose	Deliverables	Progress to Date
2022	ET22SWE0023 - Occupancy-based Thermostats for Commercial Offices	The proposed project will assess the use of occupancy sensors in HVAC systems comprising single HVAC unit serving multiple building zones. By installing wireless connected occupancy sensors in each served space of a single system, the sensors can communicate with the system thermostat to shut off the system when all served spaces are unoccupied. For example, this could reduce energy consumption on days when teams are working from home, during lunchtime hours, or Fridays when many businesses offer modified work hours as an employee benefit. The technology can be used in both new and existing construction. For existing construction, occupancy-based thermostat will replace or be added onto existing thermostat that	Expected ET Report	In Process

		controls the single-zone HVAC unit. The thermostat can work with any type of single-zone HVAC units, which are typically constant speed units.		
2022	ET22SWE0022 - Residential Housing Characteristics Study	This California Low-Income Residential Housing Characteristics Study project proposes to address the lack of complete data on housing structures in disadvantaged communities (DAC) and Hard-to-Reach (HTR) single family residential housing. While high level data such as number of homes in DACs and other key demographic and market information (housing age, access to broadband, etc.) can be pulled from census and other research, data on the baseline physical conditions of DAC and HTR homes is lacking (i.e., structural integrity, electrical panel	Expected ET Report	In Process

		and wire capacity, and code adherence). This data is foundational to being able to both size the total available market for emerging technologies and develop effective, properly budgeted program pathways to serve and transform these communities. The results will help facilitate deployment of emerging technologies including heat pump water heaters, heat pump HVAC, smart plug loads, efficient appliances including induction stove-tops, home networking equipment, and other decarbonization measures.		
2022	ET22SWE0021 - Residential Multi-Function Heat Pumps: Product Search	This proposed technical market characterization project will complete a product search from the largest HVAC and hot water heating equipment manufacturers to identify what residential air-to-air multi-function heat pump products are commercially available or soon to be commercially available in California. This project will be a combination of primary research surveying manufacturers as well as secondary research	Expected ET Report	In Process

		through literature searches. This project will produce a list of available products and specifications including rated efficiency energy savings estimates compared to mixed fuel and all electric baselines. This product search will inform future projects to improve equipment design, validate energy efficiency through laboratory and field demonstrations, and determine costs for equipment and installation.		
2022	ET22SWE0020 - Variable Refrigerant Flow (VRF) Refrigerant Management Market Assessment	This market assessment will provide clarity on anticipated market adoption of VRF systems, the lifetime GHG emissions potential of those systems if no action is taken, and the mitigation strategies that can be implemented to maximize that environmental, economic, and social benefits of commercial heat pumps. Additionally, the project will build upon and complement the current Commercial VRF Fuel Substitution measure development activity also being performed by Energy Solutions, by bringing in new market study	Expected ET Report	In Process

		activities including stakeholder engagement and a deeper focus on new system installations.		
2022	ET22SWE0019 - Market Potential for Heat Pump Assisted Hot Water Systems in Food Service Facilities	Electrifying the building sector is a critical step towards meeting California's decarbonization goals. Water heating for food service applications represents 340M therms of gas consumption and thus presents a significant electrification opportunity through the application of heat pump (HP) assistance. For the proposed study we will conduct a market assessment of the potential for adoption of heat pump-assisted hot water systems (HPaHWS) in food service facilities. This market assessment will evaluate the total reachable market and the market penetration potential for HPaHWS. We will also address the market barriers and opportunities for adoption of HPaHWS as they currently exist. This study will occur in three phases:	Expected ET Report	In Process

		Literature search, Interviews, Numerical data collection and analysis.		
2022	ET22SWE0017 - Commercial and MF CO2-based Heat Pump Water Heater Market Study and Field Demonstration	The study will build on existing research and non-residential HPWH initiatives with a focus on the California market, policies, rate structures, efficiency programs, demand flexibility programs, and market barriers. The field study will evaluate product performance and impacts on energy, cost, and greenhouse gas emissions (GHG) of the technology relative to baseline natural gas as well as load flexibility capabilities in the context of CA rates and the new Total System Benefit (TSB) metric for EE programs. The product will be installed,	Expected ET Report	In Process

		monitored, and analyzed at two participant MF sites.		
2022	ET22SWE0010 - All-Electric Commercial Kitchen Electrical Requirements Study Evaluation	This study will identify the electrical service requirements for various sizes of foodservice facilities such as quick serve, full service, cafeterias, and hospitality. This will help understand the costs, electrical load requirements, electrical service upgrade costs, and potential electrical load growth for commercial foodservice facilities in CA in converting to all-electric kitchen designs. We would work with market actors such as design/build firms to develop prototype buildings for electrical service requirements. Once the electrical service requirements have been developed for multiple prototype foodservice facilities, cost research will be completed to determine the cost of upgrading electrical service for an all-electric kitchen. Based on	Expected ET Report	In Process

		the electrical service requirements for the foodservice prototypes, the study will estimate the increased load associated with converting all foodservice facilities in CA to all-electric kitchen designs.		

Table B-4: DRET Projects

Project Start Year	Project Name	Purpose	Funding	Deliverables	Progress to Date
2017	Lab Test to Understand Existing Technologies' Ability to meet CAISO Telemetry Requirements for PDR	to explore the technical feasibility of the second solution set: using a Zigbee to broadband gateway communicating to a cloud RIG. The lab study tested two devices: the Rainforest EAGLE and the	$100,001 to $250,000	DRET Report	Completed

		Universal Devices ISY and used Olivine's CAISO approved RIG			
2017	Title 24 – Marketing Education and Outreach	to educate and inform key market actors who will be impacted by the requirement or can exert an impact throughout the compliance industry. These include equipment manufacturers and design professionals, installers that implement the designs, acceptance test technicians that verify the proper operation, and building department staff that enforce the requirements	$100,001 to $250,000	DRET Report	Completed
2017	Telemetry Field Study	To evaluate ability for Demand Response Providers (DRPs) to meet the telemetry requirements in a cost-effective manner could unlock more DR to be bid into the wholesale market and meet the various needs of the grid	$100,001 to $250,000	DRET Report	Completed

2017	Automated Demand Response (ADR) Assessment of Residential Incentives and Technologies	to conduct a review of the PG&E's current ADR program design and extract how the lessons learned to date can provide information for further enhancement to the ADR program	$250,001 to $500,000	DRET Report	Completed
2018	Expansion of the Deemed Auto-DR Express/Fast Track Solutions	to increase automated demand response market penetration of SMB customers by expanding SMB eligible measures, adding additional facility types	$100,001 to $250,000	DRET Report	Completed
2018	Secured Data Sharing to improve residential DR programs' enrollment process	to collect information in order to create a smooth and secure customer authentication, authorization, and enrollment framework for DR pilots and programs in the future	$100,001 to $250,000	DRET Report	Completed
2018	Watter Saver Pilot	to test program implementation approaches that can be used for an actual program if the AB 2868 proposal is approved or in the alternate if the EE or DR programs leverage water heating for Energy Efficiency (EE) and DR benefits in the future	$250,001 to $500,000	DRET Report	Completed

2018	Connected Home Product Bundle Field Study	to explore the way that customers are currently interacting, and could interact, with new Energy Management Technologies (EMTs) for a variety of different energy management-related applications	\$100,001 to \$250,000	DRET Report	Completed
2018	Testing Statistical Sampling Methodologies and Alternative Baseline	to develop and analyze a Type-II methodology so that all residential customers may be able to participate in CAISO’s wholesale markets	\$100,001 to \$250,000	DRET Report	Completed
2018	GHG Grid signal indicator lab test	to confirm that smart devices can be automatically controlled by a continuous/high frequency dispatch Demand Response (DR) signal (based on a combination of near-real-time GHG data from power grid operators and a forecast of grid conditions over a 30-day planning horizon) in a lab environment	\$100,001 to \$250,000	DRET Report	Completed

2018	Integrated Energy Efficiency and Demand Response Programs: Breaking Down Silos	to review experiences with integrated EE/DR programs. Key objectives will be to assess promising opportunities, identify barriers, and recommend supportive policies for greater integration of utility EE and DR programs that yield greater benefits to customers at lower costs than would separate programs	$100,001 to $250,000	ACEEE Report	Completed
2018	Bundling Energy Efficiency with Distributed Energy Resources	to explore projects that have bundled technologies and look at existing program offerings for efficiency retrofits, distributed energy resources, energy storage, and electric vehicle integration	$100,001 to $250,000	ACEEE Report	Completed
2019	Research project on the approach to calculate ADR control incentives	to engage in an approximately one-year research project to identify the new deemed approach and values for ADR control incentives	$100,001 to $250,000	DRET Report	Completed

2019	Evaluate 3rd parties interest on residential digital rate	to evaluate 3rd party (example: IDSM aggregators and smart energy vendors) interest in receiving residential digital rate in order to help residential customers to be successful when enrolling a dynamic rate such as TOU, EV and Smart Rate	$500,001 and up	DRET Report	In process
2020	Develop a residential ADR incentive for EV Charging Controls	to develop a residential ADR incentive for EV charging controls, this study will test EV charging controls in a field setting and measure the DR impact of such technologies	$500,001 and up	DRET Report	Completed
2020	Using voice automation technology for load management	to leverage residential voice assistants technology (such as Amazon Alexa, Google Home) to educate residential customers on energy usage and bill forecast, rates and Time-Of-Use automation/optimization, available of Internet-of-Things (IoT) and connectivity, configuration, and notification on utility information	$250,001 to $500,000	DRET Report	In process

2020	Heat Pump Water Heater barriers and mid-stream solution study	to identify potential solutions to barriers on HPWH technology, with a focus on leveraging mid-stream channels such as contractors, distributors, and retailers to increase adoption of this technology	$250,001 to $500,000	DRET Report	In process
2021	BTM Battery for Load Management Study	to collect data such as customer load performance and effectiveness of different algorithm during 2021 and 2022 to inform optimal program design for aggregators and customers with a BTM battery, which would help the DR team to file the 2023-2027 DR funding application in November 2021	$500,001 and up	DRET Report	In process
2021	New DR Program/Rate designs for Ag customers	to collect data on new DR Program/Rate designs for Ag customers during 2021 in order to create a draft DR program design for agricultural and irrigation customers to be filed by PG&E in November 2021 for the 2023-2027 DR funding application	$250,001 to $500,000	DRET Report	Completed

2021	TOU optimization study with smart technologies	to evaluate if residential smart technologies such as smart thermostat can optimize TOU customers HVAC energy use in order to shift customers energy usage from peak to non-peak and potentially result in customers' bill saving	$500,001 and up	DRET Report	Completed
2021	Residential Battery as Virtual Power Plant (VPP) Study	to evaluates how BTM residential battery system can be used to provide value to the customers and the grid during grid emergency	$100,001 to $250,000	DRET Report	Completed
2022	Residential Smart Panel Lab and Field study	to evaluates the function of smart panel	$500,001 and up	DRET Report	In process

APPENDIX C: Pacific Gas and Electric Company's EPIC 1, 2, & 3 Benefits Impact Report

Introduction

California Public Utilities Commission (Commission) Decision (D.) 21-11-028 ordered the IOUs to:

- Coordinate with the California Energy Commission (CEC) and the Commission's Energy Division staff to develop a single, uniform benefits analysis framework and set of metrics that enable the evaluation and tracking of the benefits of all EPIC projects.[41]
- File a report documenting their success to-date of the EPIC projects under its administration, using the metrics they are ordered to create in OP 12, and in working with Commission's Energy Division staff.[42]

PG&E has coordinated extensively with SCE, SDG&E, the CEC, and Commission Energy Division staff to create a uniform framework for benefits analysis of all EPIC projects. This framework is the basis for the summaries of qualitative and quantitative benefits in this report for all of PG&E's completed EPIC 1 & 2 projects, as well as its active EPIC 3 projects.

PG&E's EPIC projects benefit its customers by providing a means to test and evaluate the integration of technologies and solutions on the electric grid. As a planner and operator of the grid, PG&E's administration of EPIC supports California's energy and environmental policies and key Commission proceedings. Examples of PG&E's EPIC program successes include the following:

- EPIC 1.01 - *Energy Storage End Uses* introduced the first utility-owned battery storage systems to help establish CAISO's new NGR market for battery participation and

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41. D.21-11-028, OP 12, at p. 57.
42. *Id.*, OP 13, at p. 58.

resolved multiple implementation issues with the NGR market model along the way. This served to enable the participation of future storage resources in the market, which now includes PG&E's own Elkhorn Energy Storage system. This project will enable $16 million per year in savings and reduce environmental emissions by 7,000 tonnes of CO_2 per year from PG&E BESS participation in the market.

- EPIC 1.05 - *Demonstrate New Resource Forecast Methods to Better Predict Variable Resource Output* deployed a new meteorological model that drastically improved the resolution of PG&E's weather modeling capabilities from 15km to 3km resolution and provided foundational improvement across a number of applications including winter storm and wildfire risk management. It is estimated that these capabilities enable the avoidance of 15.2 million customer minutes of interruption (CMI) per year and an associated $40.8 million per year in avoided customer economic impact.
- EPIC 1.14 - *Next Generation SmartMeter Telecom Network Functionalities* developed the foundation for PG&E's SmartMeter Partial Voltage Detection system, which is now deployed across PG&E's service area. The faster detection of issues across PG&E's system enabled by this technology reduces 8 million CMI per year and an associated $22 million per year in avoided customer economic impact.
- EPIC 2.34 - *Predictive Risk Identification with Radio Frequency (RF) Added to Line Sensors* demonstrated Early Fault Detection (EFD) sensors that proved to be highly effective at identifying a wide range of developing asset issues early and pinpointing the geographic locations of the issues with high precision. As a result of the successful demonstration, PG&E has begun working to deploy these sensors on 75 distribution feeders, which is expected to improve operating efficiency and reduce operating costs by $6 million per year.
- EPIC 3.03 - *Distributed Energy Resource Management System (DERMS) and Advanced Distribution Management System (ADMS) Advanced Functionality* developed and deployed a low-cost system to allow customers with large DERs to save around a total of $2.25 million per year in sending required telemetry data from their DERs back to PG&E.

- EPIC 3.11 - *Location-Specific Options for Reliability and/or Resilience Upgrades* pioneered multi-customer microgrid capabilities and operationalized the first multi-customer microgrid in PG&E's service area in collaboration with the CEC and numerous other parties. The foundational capabilities developed through this project directly defined the tariff structures and interconnection processes of PG&E's broader Community Microgrid Enablement Program (CMEP) and the Microgrid Incentive Program (MIP), which are now in the process funding the establishment of approximately a dozen microgrids. The associated reliability benefit attributed to this EPIC project is 160,000 CMI per year and an associated $3.9 million per year in customer economic benefit.
- EPIC 3.20 - *Data Analytics for Predicative Maintenance* leveraged a range of existing PG&E data sources to develop and deploy an industry-leading analytical model for identifying problems with distribution transformers with a high degree of accuracy. This model has been transitioned directly into operational use, has already led to numerous successful interventions, and is expected to save customers 1.2 million CMI per year and an associated $3.2 million per year in customer economic benefit by preventing outages caused by failed distribution transformers.

Coordination

D.21-11-028 instructed the IOUs to coordinate with the CEC and Commission staff on a common benefits analysis framework and set of metrics.[43] Starting in June 2022, PG&E and the other IOUs began conducting virtual bi-weekly meetings. As a result of these meetings, Utility staff developed the working Utility EPIC benefits framework which is designed to demonstrate the realized and potential benefits to ratepayers from EPIC research and demonstration investment. The Utility EPIC Administrators and staff presented the working benefits framework to both the CEC and Commission staff and incorporated their suggestions and comments into the final working framework. Once the benefits framework was established, the

43. D.21-11-028, OP 12, at p. 57.

EPIC staff began developing their individual Benefits Impact Reports. They continued to meet to ensure a uniform approach across the IOUs. The result of this continuous coordination process is reflected in the following PG&E Benefits Impact Report.

Benefits

The following benefits analysis framework aligns with the mandatory guiding principle of EPIC, to provide ratepayer benefits within the CPUC-defined areas of increasing reliability, improving safety, increasing affordability, improving environmental sustainability, and improving equity. Because the Utility-funded portions of the EPIC program involve the demonstration and evaluation of pre-commercial technologies, benefits are dependent on both qualitative and quantitative factors. To capture the benefits of pre-commercial demonstrations' inherent knowledge and data seeking objectives, supplemental quantification and qualification can be attributed to the following benefit areas: Adoption of EPIC Technology, Effectiveness of Information Sharing, Technology Development Progress, Support of CPUC Proceedings or State Policy, and development of Industry and/or Company Standards. The following measurement areas are the most closely aligned of the benefits in D.13-11-025 Attachment 4, although there may be additional benefits from Attachment 4 that may be applicable to future EPIC projects. The resources and tools used by the IOUs to identify, qualify, and quantify benefits are listed in Table C-1, below.

Table C-1 Joint IOUs Benefits Framework

Benefit Area	**Measurement**	**Resources/Tools Applied**
Reliability	1. Equipment service life extension 2. Outage number, frequency and duration reductions	• Final Reports • Internal Presentations • SME Estimates • ICE Calculator • Various Models

Benefit Area	Measurement	Resources/Tools Applied
	3. Reduction in system and equipment failures 4. Improved reliability to DAC customers	
Safety	1. Worker safety improvement and hazard exposure reduction 2. Public safety improvement and hazard exposure reduction 3. Safety improvements targeted towards DAC	• Final Reports • Internal Presentations • SME Estimates • https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics/light-duty-vehicle • Various Models
Environmental Benefits	• Habitat area disturbance reductions	• Final Reports • Internal Presentations • SME Estimates • https://www.californiadgstats.ca.gov/charts/

Benefit Area	Measurement	Resources/Tools Applied
	• Reduce GHG emissions (MMTCO_2e) • DAC Residents impacted by reduced emissions	• CalEnviroscreen 4.0 • Various Models
Economic Benefits	1. Maintain/reduce O&M costs 2. Maintain/reduce capital costs 3. Peak load reduction 4. Reduced cost of DER adoption 5. Reduced cost of DER adoption for DAC. 6. Avoided customer energy use 7. Follow-on funding to projects 8. Customer bill or interconnection savings	• Final Reports • Internal Presentations • SME Estimates • Various Models

Benefit Area	Measurement	Resources/Tools Applied
	9. CO_2 equivalent savings	
Effectiveness of Information Sharing	1. Number of industry sharing events/papers presented 2. Number of times reports are cited in scientific journals and trade publications for selected projects 3. Number of information sharing forums held 4. Stakeholder attendance at workshops 5. Results provided to standards development organizations	• Final Reports • Internal Presentations • External presentations • Other published papers • SME Estimates

Benefit Area	Measurement	Resources/Tools Applied
Adoption of EPIC Technology	1. EPIC project results referenced in regulatory proceedings 2. Number of technologies/use cases demonstrated, in direct use post-EPIC 3. Number of technologies included for funding in the GRC, or for which post-EPIC funding has otherwise formally been committed	
Support of CPUC Proceedings or State Policy	1. Specific CPUC proceedings or state mandates	

Benefit Area	Measurement	Resources/Tools Applied
Informed Industry and/or Company Standards	1. Specific standards which were created or updated	

The sections below summarize the identified benefits resulting from and expected to result from PG&E's project work in EPIC 1, 2 and 3. Every completed PG&E EPIC Project concludes with the writing of a detailed closeout report. As of the filing of this benefits and impact report, all PG&E EPIC I and EPIC II projects are complete, and all EPIC III projects are in-flight and will be completing from Q4 2022–2024. For additional information, completed project closeout reports are available on the PG&E website at https://www.pge.com/epic.

EPIC 1 Project Benefits

Project 1.01 - Energy Storage for Market Operations

In 2010, Assembly Bill (AB) 2514 directed the CPUC to set targets for the procurement of energy storage systems while noting that "there are significant barriers to obtaining the benefits of energy storage systems". Two years later in 2012, D.12-08-016 identified nine key barriers to energy storage including "Lack of Commercial Operating Experience," "Evolving Markets," "Lack of Transparency… in Wholesale Price Signals," "Lack of Well-Defined Interconnection Processes," and "Lack of Cost-Effectiveness Valuation Method" and in the following year, D.13-10-040 set the energy storage target for PG&E at 580 MW.

This project successfully addressed these barriers by utilizing PG&E's Vaca-Dixon (2 MW/14 MWh) and Yerba Buena (4 MW/28 MWh) Battery Energy Storage Systems (BESSs) to help establish and participate in CAISO's Non-Generator Resource (NGR) market model. PG&E developed and deployed a foundational automated communications and control solution to fully utilize and evaluate BESS fast-response functionalities. The two batteries from the demonstration continued to operate in production with the CAISO market well after the project concluded and are now undergoing decommissioning as they have reached the end of their useful life.

Benefits

- **Economic Benefits**
    - This project directly helped to establish CAISO's NGR market and developed automated communication and control capabilities to enable use cases including ancillary services such as frequency response (4 second response to regulate frequency) and energy arbitrage (buying electricity at low prices and selling at high prices). The project has enabled the market participation of PG&E's Elkhorn Energy Storage project (182.5 MW/730 MWh) at Moss Landing Substation. The Elkhorn system is a Lithium-Ion BESS and is the only BESS PG&E currently has participating in the CAISO market. The BESS started operations in April 2022 and its initial performance shows that ancillary services as well as energy arbitrage have significant financial benefit. Operational data from the Elkhorn Energy Storage system shows that ancillary services such as frequency regulation project to account for $9M per year in benefit and energy arbitrage projects to account for $7M per year for a total of about $16M per year.[44]
- **Environmental Benefits**
    - BESS technology displaces the need for dispatchable energy generation sources which are typically natural gas-fired power plants. Since the Elkhorn Energy Storage project is the only PG&E BESS currently participating in the market, the CO_2 reduction by charging off peak and discharging on peak/ramp is estimated to

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44. Assuming the preliminary data from Elkhorn Energy Storage project is roughly representative of its annual operation, the current economic benefits are extrapolated on an annual basis. The annual projections, before attributing to EPIC are $18M per year for frequency regulation and $14M per year for energy arbitrage, for a total of $32M per year. The calculation assumes an attribution factor of 50 percent for these benefits to EPIC 1.01, which results in the benefit of $16M per year attributed to EPIC 1.01.

be 7,000 tonnes of CO_2 reduced per year[45]. This value is only for one CAISO-connected battery system and there will likely be many CAISO-connected Battery Energy Storage Systems connected to the California grid in the future.

- **Adoption of EPIC Technology**
  - This foundational project introduced the first utility-owned battery storage resources to help establish CAISO's new NGR market/model for battery participation and resolved multiple implementation issues with the NGR market model along the way. This served to enable the participation of future storage resources in the market, which now includes PG&E's own Elkhorn Energy Storage system.
- **Support of CPUC Proceedings or State Policy**
  - Assembly Bill (AB) 2514 Energy Storage Targets
  - D.12-08-016 Adopting Proposed Framework for Analyzing Energy Storage Needs
  - D.13-10-040 Adoption of Procurement Targets for Viable and Cost-Effective Energy Storage Systems
  - R.15-03-011 Energy Storage Procurement Framework and Design Program

Quantitative Benefits Summary

Benefit Area	**Measurement**
Environmental Benefits	7,000 tonnes/year of CO_2 reduction
Economic Benefits	$16,000,000/year

45. Assuming the 730 MWh Elkhorn BESS discharges 60 percent of its nameplate energy capacity per day, charging in the day when renewables are plentiful at 0.17 tonnesCO2/kWh (from CAISO) and discharging during the peak or ramp period at 0.26 tonnesCO2/kWh (from CAISO), the GHG reduction would be 14,000 tonnes of CO2 reduced per year before attribution to EPIC. The calculation assumes an attribution factor of 50 percent for a resulting allocation of 7,000 tonnes of CO2 reduced per year attributed to EPIC 1.01.

Project 1.02 - Demonstrate Use of Distributed Energy Storage for Transmission and Distribution Cost Reduction

EPIC project 1.02 demonstrated the ability to use energy storage to delay capacity expansion while improving reliability. A Battery Energy Storage System (BESS) was deployed at the Browns Valley substation (500 kW/2 MWh). This was integrated into PG&E's Supervisory Control and Data Acquisition (SCADA) system to deliver autonomous distribution peak shaving functionality. The project has been providing benefits at the Browns Valley substation since 2017 and is still in operation. During the project, the energy storage system provided peak-shaving functionality for two peak events in 2017 during heat waves. Since then, it has provided peak shaving functionality in many peak events including in the summer of 2022.

Benefits

- **Economic Benefits**
  - The project demonstrated that it is possible to perform "distribution deferral" (also referred to as "peak shaving") to address a capacity limitation in a particular part of the electrical system and defer or eliminate the need for a capacity expansion that would only be needed to accommodate a few peak hours per year. Despite its name, distribution deferral is not limited to the distribution system as it can be applied to the transmission system as well. PG&E estimates that a future distribution deferral project between 2-10MW may save $1-3M and that a transmission deferral projects around 30 MW in size may save $5-15M[46]. This Browns Valley Project was a smaller demonstration project and is estimated to have saved around $1M in avoided distribution upgrade costs.
- **Effectiveness of Information Sharing**
  - DistribuTECH 2017: San Diego, California | February 2, 2017

46. A report called EPIC 1.02 Potential Cost Savings was created to supplement the EPIC 1.02 final report to discuss potential cost savings from distribution deferral projects. These estimated savings are from that report and are from SME estimates at the time.

- Benchmarking conference call with Puget Sound Energy | April 17, 2017
  - EPRI Energy Storage Integration Council meeting: Denver, Colorado | April 21, 2017
  - Benchmarking conference call with San Diego Gas & Electric Company | April 27, 2017
- **Support of CPUC Proceedings or State Requirements**
  - Assembly Bill (AB) 2514 Energy Storage Targets
  - D.12-08-016 Adopting Proposed Framework for Analyzing Energy Storage Needs

Quantitative Benefits Summary

Benefit Area	Measurement
Economic Benefits	$1,000,000

Project 1.05 - Demonstrate New Resource Forecast Methods to Better Predict Variable Resource Output

This project successfully developed and demonstrated a new mesoscale meteorological model to provide much more granular and accurate weather forecasting input to PG&E's storm damage prediction model and to other PG&E forecasting applications, such as catastrophic wildfire risk, large storms and photovoltaic (PV) generation. This model is known as the PG&E Operational Mesoscale Modeling System (POMMS) and it has improved the accuracy of forecasting for large storms, allowing for increased efficiencies in storm preparation, as well as enhanced the accuracy of identifying fire risks, helping enable improved reliability and safety. The storm damage prediction model is known as the Storm Outage Prediction Project (SOPP) and the fire danger model is known as the Fire Danger Rating System (FDRS). The POMMS model also enables leveraging of granular solar irradiance data in a new framework to improve PG&E's ability to understand the impacts of PV generation for grid management.

Before this project, the industry standard models used by PG&E for forecasting applications used a resolution of 12 km and lacked the spatial resolution needed to predict detailed surface conditions needed for storm damage modeling. EPIC 1.05 improved the resolution significantly to use 3 km resolution and made detailed modeling possible. In recent years following the EPIC 1.05 project, the POMMS model's resolution has been further improved from 3km to 2km. Over the years since the 1.05 project, other valuable applications have been found for the POMMS model's data, such as using it in Public Safety Power Shutoff (PSPS) decision making and the activation of Enhanced Powerline Safety Settings (EPSS) which has now expanded to all 25,500 distribution line miles in High Fire Risk Areas in PG&E territory.

Benefits

- **Safety**
  - Implementation of the SOPP model is correlated with an improvement in the accuracy of forecasting for large storms. This has enabled better preparation and staging of crews at appropriate locations to restore power more quickly. This resulted in:
    - Public safety benefits from faster re-energization to critical infrastructure and to residences where electricity is a medical necessity.
    - Employee safety benefits by limiting the travel time to a job location during potentially hazardous driving conditions.
  - Public safety benefitted from the more granular weather data and better modeling of fire risks from the FDRS model, which evolved into a model that PG&E currently uses today for the Fire Potential Index, the PSPS, and the EPSS modeling systems.
- **Reliability**
  - The SOPP model increased customer reliability by informing PG&E on how to better prepare and stage crews at appropriate locations to restore power more quickly during storms. Conservatively estimating that drastically increasing the resolution of weather forecasting capabilities from 15km before the 1.05 project to 3km and then ultimately to 2km, resulted in a 1 percent improvement in

storm response, this results in a reduction of 8.4 million customer outage minutes.[47]

  - Increasing the resolution of weather forecasting, including wind forecasting, has also allowed for improved fire risk forecasting and better-informed PSPS implementation. Conservatively estimating that having these better capabilities has allowed for 1 percent avoided PSPS outage impact translates to roughly 6.7 million in avoided customer minutes of interruption (CMI).[48]
  - The solar modeling system is used to improve PV load forecasting and it takes into account residential solar to ensure grid operators have the most accurate information to balance supply and demand and ensure grid stability.

- **Economic Benefits**
  - The benefits for the increased reliability from the SOPP model results in an economic benefit of $22.7 million per year.[49]
  - The benefits for the increased reliability from the better-informed PSPS modeling results in an economic benefit of $18.1 million per year.[50]

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47. This uses the total actual customer minutes of interruption (CMI) of 1.7 billion customer-minutes from all non-PSPS storm events from PG&E's 2021 Annual Electric Reliability Report (https://www.pge.com/pge_global/common/pdfs/outages/planning-and-preparedness/safety-and-preparedness/grid-reliability/electric-reliability-reports/CPUC-2021-Annual-Electric-Reliability-Report.pdf), a 1 percent reduction in storm related customer outages, and a 50 percent attribution to EPIC 1.05. This results in 8.4 million customer outage minutes avoided annually.

48. Average annual total PSPS-related CMI for distribution customers across 2020 was 1.3 billion customer minutes. Conservatively estimating that better modeling capabilities avoided 1 percent of this customer impact and using a 50 percent attribution to EPIC 1.05 results in 6.7 million customer minutes of interruption avoided.

49. Assuming a CMI multiplier of $2.69 per customer-minute and using the previously projected reliability benefits of 8.4 million CMI, the economic benefit of improved modeling for non-PSPS storm events is $22.7 million per year.

50. Assuming a CMI multiplier of $2.69 per customer-minute and using the previously projected reliability benefits of 6.7 million CMI, the economic benefit of improved modeling for PSPS events is $18.1 million per year.

- Better fire modeling with FDRS improved PSPS and EPSS forecasting that likely resulted in fewer ignition events and less damage to property.
- **Lower GHG Emissions/Air Pollution**
  - The contribution to improved PSPS and EPSS models likely resulted in fewer ignition events and fewer fires which result in lower GHG emissions and decreased air pollution.
  - The solar modeling system is used for improved PV load forecasting, and it takes into account residential solar to allow for the increased adoption of PV resources and displacing the need for GHG generating sources.
- **Support of CPUC Proceedings or State Requirements**
  - R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans Pursuant to Senate Bill 901 (2018)
- **Informed Industry and/or Company Standards**
  - PG&E standard TD1464S - Preventing and Mitigating Fires While Performing PG&E Work

Quantitative Benefits Summary

Benefit Area	Measurement
Reliability	15.2 million CMI/year avoided
Economic Benefits	$40,800,000/year

Project 1.08 - Distribution System Safety and Reliability through New Data Analytics Techniques

The objective of this project was to demonstrate a visualization and decision support system to support PG&E's risk management efforts to enhance public and system safety as well as improve asset management strategies and investment plans for Electric Operations (EO). The software application developed was the System Tool for Asset Risk (STAR). The concept of STAR is to integrate electrical asset and system data from multiple sources to calculate individual asset and system risk scores based on severity of risk and probability of occurrence.

STAR is currently available in PG&E's ATLAS, which is an Information Technology (IT) integrated portfolio management system and system of record. STAR is used by PG&E electric distribution and is an analytics application now under the name APP-1889 Tool for Asset Risk. It currently is on the Amazon Web Services (AWS) platform and there are plans for it to be moved to PG&E's central Foundry platform.

Benefits

- **Safety**
  - The scoring of individual asset and system risk through the STAR tool helps to enable focusing on higher risk assets, and the identification of work that has the greatest likelihood of improving public safety.
- **Reliability**
  - The STAR platform developed through this project provides improvements to the calculation and visualization of asset system risk, which in turn enables the development of improved asset strategies to improve system reliability.
- **Economic Benefits**
  - Improvements in the asset risk quantification improve prioritization of risk mitigations and enable more efficient allocation of resources and cost reduction.
- **Support of CPUC Proceedings or State Requirements**
  - Risk Assessment and Mitigation Phase (RAMP)[51]

51. https://docs.cpuc.ca.gov/PublishedDocs/SupDoc/A2006012/2881/342386992.pdf.

Project 1.09A - Test New Remote Monitoring and Control Systems for Existing Transmission & Distribution Assets: Close Proximity Switching

In 2016, PG&E had over 20,000 oil filled sub-surface 200-amp, three phase Load Break Oil Rotary (LBOR) switches in its underground distribution system. PG&E estimates there were approximately 900 LBOR switches without oil level indicators and another 1,400 pre-1972 units which were considered high risk due to their age and the lack of knowledge of the condition of the oil inside the tank (even with an oil-level indicator). Traditional operation of LBOR switches required an employee to manually stand over the enclosure, use an insulated tool called a "hot stick", and turn the switch nob off or on. Although the hot stick protects the employee from electric shock, the employee can still be potentially injured if a failure/explosion were to occur due to low oil, mechanical fatigue, or dielectric integrity of the fluid. Failed oil switches have resulted in injury events, triggered customer outages, and/or caused property damages.

This project focused on increasing system reliability and improving the safe operation of three-phase Load Break Oil Rotary switches, which are used for making or breaking the path in an electrical circuit. In both a lab and field setting, this project successfully demonstrated and evaluated various robotics that would allow PG&E workers to remotely operate certain subsurface or underground (UG) oil switches. As a result of this EPIC project, PG&E subsequently purchased 106 remote switching devices which were distributed across the territory. It is now a company standard to only operate energized LBORs without sight glasses with the use of the remote operator equipment successfully demonstrated by EPIC 1.09A. This important safety device provides an interim solution during the implementation of a multi-year switch replacement program with the goal of completing all LBOR switch replacements by 2040.

Benefits

- **Safety**
  - Increased employee safety during sub-surface oil-filled switch operations by eliminating the need for an employee to perform manual switching by use of a "hot stick".

    - Increased public safety since the operator has better visibility of pedestrians when he/she is ready to execute the switching command remotely.
- **Reliability**
    - Should a circuit failure occur, this device ensures that PG&E has the ability to confidently and safely operate Load Break Oil Rotary (LBOR) switches to reduce customer outage/interruption time.
- **Informed Industry and/or Company Standards**
    - PG&E created or amended guidance documents to include close proximity switching devices in operations. The relevant standards are:
        - TD-2908P-01 – Distribution Switching Procedures
        - TD-2908P-01-JA280 –Remote Operator for Load Break Oil Rotary (LBOR) Switches
        - TD-2908M – Electric Distribution Field Switching Manual
        - 039954 – Installation of 200-Amp Subsurface Sectionalizing Switches
        - TD-2908B-008 – Load-Break Oil Rotary (LBOR) Switch Operating Procedure
- **Adoption of EPIC Technology**
    - PG&E initiated a General Rate Case (GRC) request for funding totaling $600,000 and this resulted in the purchase of 106 remote switching devices which were distributed across the territory according to the number of LBORs in operation in each division.

Project 1.09B/10B - Test New Remote Monitoring and Control Systems for T&D Assets/Demonstrate New Strategies and Technologies to Improve the Efficacy of Existing Maintenance and Replacement Programs

This project successfully demonstrated methods of evaluating and potentially extending the longevity, resiliency and data integrity of Supervisory Control and Data Acquisition (SCADA) condition-monitoring components over time. The overall strength of the monitoring and communication systems currently installed across the distribution network was confirmed and methods for improving the life and data integrity of its components were demonstrated. Real-time condition monitoring of this system provides a key input to support proactive mitigation of equipment-related issues.

Benefits

- **Safety**
    - Ambient temperature and oil sensors are designed to alarm upon conditions such as overheating of the equipment. Overheating could result in asset failure, potentially resulting in a safety risk. A well-functioning monitoring system reduces this safety risk.
- **Reliability**
    - The project confirmed that physical connections installed in SCADA systems are generally reliable and resilient. It also highlighted conditions where physical connection issues could occur such as in high humidity environments and with bare wire connections as opposed to pinned connections.
- **Economic Benefits**
    - Extending the life of condition monitoring equipment may reduce the life cost of installation, maintenance, repair, and replacement of this equipment. Additionally, being aware of potential problems with network equipment helps PG&E respond to required repairs before asset failures occur and can potentially

reduce the overall cost of operating the distribution network system by extending the life of major assets.

Project 1.09C - Test New Remote Monitoring and Control Systems for T&D Assets, Discrete Series Reactors

This project successfully demonstrated new Discrete Series Reactor (DSR) technology deployed directly onto transmission conductors to detect potential overloads and increase line impedance to shift this load to parallel facilities. These devices can potentially enable optimization of line flows, mitigation of overloads, and delay of costly new transmission line or reconductoring projects.

Benefits

- **Safety**
  - Transmission line overloads can potentially cause asset damage or create a safety hazard with the line. DSRs can be deployed directly onto transmission conductors to detect potential overloads and increase line impedance to shift this load to a lower load conductor.
- **Reliability**
  - Some PG&E transmission lines experience overloads following n-2 or n-1-1 outages that are mitigated by the use of Special Protection System (SPS) load tripping. The use of DSRs on such a line could reduce the need for SPS load tripping, thereby potentially reducing reliability impact.
- **Economic Benefits**
  - Currently, mitigation of transmission line overloads often leads to investments to increase capacity such as reconductoring the line. DSRs could be implemented to defer the need for a higher cost transmission capacity upgrade, reducing the cost of overload mitigation. As compared to traditional transmission investments, DSRs can be deployed several years faster at a significantly lesser cost.

Additionally, DSRs offer portability and flexibility, whereas traditional upgrades are permanent installations.

- **Adoption of EPIC Technology**
    - The project transitioned to production with the installation of 90 DSRs on the Los-Positas Newark 230kV transmission line, which reduced line flow and balanced the three phases. PG&E has adopted the DSRs as a part of the Transmission options to be considered when reviewing capacity needs.

Project 1.14 - Next Generation SmartMeter Telecom Network Functionalities

This project evaluated the radio mesh telecommunications network that connects SmartMeter devices across PG&E's territory, including demonstration of new potential use cases for SmartMeters and the network. The project created a methodology to determine available bandwidth, tested a variety of smart grid devices to demonstrate their potential to leverage the network for communications, and demonstrated potential enhancements to the existing outage reporting capabilities of SmartMeter devices.

Many programs and capabilities originated from this one project such as the Smart Streetlights and Smart Poles demonstration, the Next Generation Network Hardware, Transformer Monitoring Devices, the SmartMeter Partial Voltage Detection capability, and Phase Identification which led to EPIC 2.14.

Benefits

- **Safety**
    - This project developed the foundation for PG&E's SmartMeter Partial Voltage Detection capability that has subsequently been deployed across PG&E's system and allows for automated detection of wires down events and other grid issues through the SmartMeter network, and faster resolution to minimize the risk to

the public. The technology is useful for identifying the exact locations of faults for first responders.

- **Improve Reliability**
  - This project increased the work done analyzing outage logs and this helps identify the scope of outages more quickly. The project also demonstrated technologies that provide greater reliability through improvements in outage reporting, distribution automation control and telemetry, and monitoring and control of the electric grid.
  - The capabilities developed through this project evolved into PG&E's SmartMeter Partial Voltage Detection system, which is now enabled across PG&E's service area. When this system detects a fault first, it beats the other available methods by approximately 20 minutes.
- **Economic Benefits**
  - The quicker detection of downed wires and other grid issues results in a faster restoration of power to customers. Since the system is deployed across all the territory, this corresponds to a SAIDI reduction for the system which results in an estimated 8 million in reduced CMI per year and corresponding economic benefit of roughly $22,000,000 per year.[52]
  - Leveraging the SmartMeter Network for non-metering applications and devices (that would otherwise require a separate communications network) has the potential to lower costs for smart grid devices and applications that can help

52. This assumes that the improvement in time for outage detection is 20 minutes when partial-voltage detects the outage first (SME estimate) and applies it to the 5.5 million customers in PG&E territory. Conservatively, partial-voltage detection identifies the fault first 15 percent of the time (SME estimate). Because enhancement of this capability continued after the EPIC project, 50 percent of the calculated benefits are attributed to this EPIC project. With a 50 percent attribution to EPIC 1.14, this results in an average outage reduction of 1.5 minutes and a corresponding estimated 8 million in reduced CMI per year. Using an outage multiplier of $2.69 per customer-minute, this results in $22,000,000 per year in economic benefit since this technology is deployed across PG&E's service area.

PG&E to deliver energy safely and efficiently. Innovative metering solutions such as Smart Streetlights and Smart Pole Meter can enable PG&E to more accurately meter electricity use. The SmartMeter Partial Voltage Detection capability was patented, and subsequently licensed, with the potential for significant royalties over the next five years that will be returned to customers.

- **Reduce GHG Emissions, Air Pollution, or Other Health Impacts**
  - The SmartPoles, by reducing hops, free up bandwidth to allow integration of other DER and connected smart devices to the grid.
  - There is a future potential application of enabling EVs. There is discussion with cities and regulators on how to incorporate EV chargers in light poles to enable streetside EV charging.
- **Adoption of EPIC Technology**
  - The Smart Streetlights and SmartPole demonstration deployed thousands of smart poles in the San Jose and Cupertino area. These SmartPoles are easy to integrate with other devices, such as the 5G communication network, which requires more cells to operate. Previously, the electric utility would require telecom companies to find their own source of power. This project enabled 5G customers to be able to connect to the network more easily.
  - This project developed significant intellectual property, as well as multiple patents and license agreements with external vendors. For example, this project developed the foundation for the capability to use the SmartMeter network to monitor for partial voltage conditions that are indicative of wires down events. PG&E has both deployed this capability in production internally, and has licensed this capability to a large vendor, who will in turn provide it to potentially numerous other utilities. Also, the “Smart Pole Meter” developed in the project, which allows PG&E to appropriately meter telecom equipment attached to streetlights, has been patented and licensed to two vendors, enabling future revenue for PG&E when cities partner with these vendors to become “Smart Cities” with expanded connectivity.

- The SmartMeter Partial Voltage Detection capability is now deployed across all of PG&E's service area. The Restoration Dashboard was transitioned to production, and the Smart Pole Meter has been deployed at limited scale, including in the city of San Jose. The project also provided insights and lessons about how to improve operations for 2020 GRC, Chapter 6: Metering.

- **Support of CPUC Proceedings or State Requirements**
    - R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans

Quantitative Benefits Summary

Benefit Area	Measurement
Reliability	8,000,000 CMI/year avoided
Economic Benefits	$22,000,000/year

Project 1.15 - Demonstrate New Technologies and Strategies That Support Integrated "Customer-to-Market-to-Grid" Operations of the Future

This project demonstrated a technology platform to visualize grid operations data to improve both real-time and short-term operational decisions, such as outage anticipation, construction planning, circuit loading research, and emergency operations. The project developed key data, system, and user experience learnings through integrating more than 20 data sources into a single visualization tool allowing users to view complex data sources in ways that were not possible through current solutions. This project formed the foundational learnings which will allow PG&E to potentially explore other complex situational awareness tools and applications to allow users to target information to help manage changes on the grid.

Benefits

- **Safety**

- The Distributed Generation Research, Circuit Loading Research, and Outage Anticipation use cases could allow operators to identify potentially dangerous reverse power flow from distributed generation assets during circuit outages.

- **Reliability**
  - The information displayed on the Interactive Map and the Outage Anticipation use case could enable grid operators to dispatch resources more effectively. Access to better and fresher data could support more effective early warnings, reduce power quality complaints, and accelerate power restoration activities.

Project 1.16 - Demonstrate Electric Vehicle as a Resource to Improve Grid Power Quality and Reduce Customer Outages

This project successfully developed and demonstrated a new Vehicle On-Site Grid Support System (VOGSS), for utility-grade power export from Plug-in Hybrid Electric Vehicle (PHEV) fleet trucks. This new technology enables a source of mobile power that can connect directly to distribution circuits, minimizing the impact of an outage for common preventative maintenance tasks such as transformer replacements. Additionally, VOGSS can provide power to facilities in emergency events, maintaining or quickly restoring service to customers.

Benefits

- **Reliability**
  - This project was executed to explicitly enable more resilient and reliable power through the substitution of truck exported power for the utility grid when a planned shutdown is needed. When the grid is down from unplanned events, VOGSS can help enable with localized re-energizing prior to a future permanent repair.
- **Economic Benefits**
  - VOGSS leverages a multi-function tool used in lieu of either greater outage exposure or increased investment in dedicated generator sets (less capital

efficient to buy another stand-alone equipment asset). Additionally, EPIC 1.16 supports the case for leveraging electric vehicles in utility fleets. Cost savings are primarily accounted from the operating savings from a plug-in hybrid electric drive system. The drive system exploits the use of lower-cost stored grid electricity as an offset to more expensive exclusively fossil-fuel-based mobility.

- **Environmental Benefits**
  - VOGSS offers a cleaner alternative to fossil-fuel based backup generation.

Project 1.18 - Demonstrate SmartMeter-Enabled Data Analytics to Provide Customers With Appliance-Level Energy Use Information

This project conducted a demonstration to understand and compare disaggregation vendors' ability to itemize monthly appliance-level usage for residential customers, as well as their current analytical capability and accuracy of their energy disaggregation software. Additionally, this project surveyed customers to understand their perception of the end-use energy presentations and the value of the disaggregated data.

Ultimately, the technology was determined to not yet be mature enough to provide to customers. The results did not achieve the disaggregation that was hypothesized at the beginning of the project. In this finding, PG&E was able to understand the current state of the technology and avoid investments that would not be beneficial to customers.

Benefits

- **Economic Benefits**
  - This demonstration identified limitations in vendors’ abilities to itemize usage. Upon the improvement of the load disaggregation capabilities, customers will be able to manage their usage more effectively and ultimately, lower their electricity costs by understanding the underlying drivers of their electricity usage. Additionally, the learnings from disaggregated billing can be used to

inform program and product designs for energy efficiency, demand response, and other programs, which may produce lower costs to customers.

Project 1.19 - Pilot Enhanced Data Techniques and Capabilities via the SmartMeter Platform

This project successfully demonstrated new ways to leverage the SmartMeter platform to provide greater visibility and granularity to additional SmartMeter data. The project proved the ability to collect power quality data and potentially enable a proactive response to address customer satisfaction concerns on voltage issues. The project also connected difficult to reach meters to the AMI network to potentially reduce manual meter reading operation and maintenance costs. Finally, the project improved the ability to identify "Line Side Tap" scenarios to improve the efficiency and effectiveness of investigating energy diversion cases and to mitigate safety hazards for customers, the public, or PG&E.

Benefits

- **Safety**
    - This technology can be used to identify unsafe energy diversions. Removing these diversions, known as "line taps", reduces house fires and the risk to people who make the connections since an unauthorized line tap requires work on a live electrical connection.
    - This technology led to other projects such as Sensor IQ that uses non-billing data such as voltage. PG&E's Electric Operations is exploring how to use this data to identify wire down conditions or monitor for overloaded transformers.
- **Reliability**
    - Giving visibility to more granular voltage data than was previously available assists in meeting CPUC Electric Rule 2 voltage service requirements for both line-to-line and line-to-neutral voltages. Meeting the voltage requirements allows the customer and utility equipment to operate properly and reduces

potential damage from over- or under-voltage. PG&E's power quality team still uses the data sources obtained from this project.

- **Economic Benefits**
    - Radio communications technologies that provide the AMI network with a longer range allows over-the-air operations rather than field visits for those meters that were outside of the AMI network coverage. This eliminates the cost of monthly manual meter reading, as well as the need for ad-hoc visits.
    - The project can be used to identify energy diversion (theft) which would require ratepayers to cover the difference in charges. The project team worked with PG&E's revenue assurance department to design a voltage level for when to send someone to investigate further. Revenue assurance still uses the data sources created by this project.

Project 1.21 - Pilot Methods for Automatic Identification of Distributed Energy Resources (such as Solar PV) as they Interconnect to the Grid to Improve Safety & Reliability

This project focused on developing and demonstrating technology to identify existence of PV systems using SmartMeter and other data not otherwise recorded in PG&E's interconnection database. Additionally, the project explored the ability of detecting underperforming or malfunctioning PV systems. The project was able to develop key inputs necessary to identify a PV system, filter for those identified systems with unauthorized interconnections, support high quality interconnection records by validating the size of PV systems, understand the limitations in the ability to detect if a PV system is underperforming or not functioning, and established a process to engage with solar customers to provide appropriate notice.

Benefits

- **Safety**

    - The algorithms developed by this project accurately predicted PV system sizes as well as unauthorized interconnections. Customers without an authorized interconnection may pose a risk to the components of the equipment and facility of the customer. Equipment failure can happen to various DG components, such as PV modules, inverters, circuit combiner, disconnecting, protection devices, and connectors. Equipment faults or over-heating can also ignite the combustible materials near the generator, causing fire damage to equipment and property.
- **Reliability**
    - The algorithms developed by this project accurately predicted PV system sizes as well as unauthorized interconnections. Underreported or inaccurately reported interconnections could lead to voltage fluctuation problems or Rule 21 violations, as well as other reliability and planning issues. Improving the accuracy of known PV interconnections, sizing and performance can improve the ability to identify root causes for voltage fluctuations. Additionally, reliably predictable generation profiles at geographically granular levels are essential for forecasting and planning purposes to proactively plan system upgrades or deferrals, if needed.
- **Economic Benefits**
    - By detecting that an existing solar customer has an unauthorized interconnection, PG&E enables customers to participate in the Net Energy Metering (NEM) rate, reducing customer costs.
- **Adoption of EPIC Technology**
    - The PV detection algorithm developed in the project successfully identified 53 suspected unauthorized interconnections (UIs) out of a sample of 72,306 customers used for the project, with model precision of 98.52 percent. Subsequent to the EPIC project, the algorithm was applied across the service territory, and identified over 2000 suspected UIs, which facilitated PG&E’s coordination with these customers.

- **Effectiveness of Information Sharing**
    - PG&E filed patent US 10,577,720-B2 on the technology developed for this EPIC project.
- **Support of CPUC Proceedings or State Requirements**
    - R.11-09-011 Rule 21, Smart Inverter
    - R.17-07-007 Streamlining Interconnection of Distributed Energy Resources and Improvements to Rule 21

Project 1.22 - Demonstrate Subtractive Billing with Submetering for EVs to Increase Customer Billing Flexibility

This project was part of a California Statewide effort to demonstrate and evaluate the use of Electric Vehicle (EV) submetering to provide EV owners access to electricity at a less expensive electric rate—without having to install an additional utility meter to an existing service. This project also assessed EV customer demand for submetering and the customer experience with submetering.

Benefits

- **Reliability**
    - Subtractive billing via third-party submetering has the potential to improve the monitoring and management of EV charging load, which can contribute to improved system reliability. However, EPIC 1.22 showed that the demonstrated approach to EV submetering was not ready to scale to the entire state at the time of the project.
- **Economic Benefits**
    - The successful use of EV submetering via charging stations could reduce the cost of EV charging, however the costs savings—an average of $374 per installation—were modest at the time of the project as compared to installing a second utility-grade meter. At the same time, to scale submetering to customers across

California was estimated to cost the utilities from $3,215,000 to $5,000,000 per utility[53] at the time. This demonstration identified that third-party EV submetering solutions were not ready to be deployed to serve the state of California, and thus this project helped to avoid the substantial cost associated with the statewide rollout of such a solution at the time.

- **Adoption of EPIC Technology**
    - PG&E identified key elements of third-party EV submetering solutions that will need to be improved before they are deployed to serve the state of California.
    - The learnings from this project enabled a successor project with EPIC 3.27.
- **Support of CPUC Proceedings or State Requirements**
    - D.13-11-002 on utility requirements for the development of the Submetering Protocol
    - R.13-11-007 Alternative-Fueled Vehicles Programs

Project 1.23 - Demonstrate Additive Billing with Submetering for PVs to Increase Customer Billing Flexibility

This project focused on developing, testing, and validating a way of collecting or estimating solar generation output data and enabling a subset of customers to view their estimated solar generation data through integration with PG&E's YourAccount website. Upon determining that using estimated PV generation data would be a viable option, the project also assessed the accuracy of the algorithm used by a third-party vendor. The project determined that additional data is necessary to develop a scalable PV generation estimate, including shading impacts, PV system tilt and azimuth, as well as weather data like fog and marine layer.

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53. By identifying that third-party EV submeters were not ready to be deployed, this project helped avoid substantial cost of a statewide rollout between $3,215,000 to $5,000,000 (SME estimate).

Benefits

- **Reliability**
  - While the project identified limitations in the existing data quality, once resolved the estimated PV generation data identified in this technology demonstration project may help PG&E understand the changing base load characteristic resulting from increased PV generation. It may also provide planners with more detailed and accurate information to better understand the gross load to properly account for actual demand on specific assets. The data could also be useful for distribution operators to more accurately quantify load masking and generate more accurate predictions of expected PV generation for short term forecasting. This could potentially help improve the distribution planning process and energy procurement.
- **Economic Benefits**
  - The use of estimated generation is more cost effective than installing submeters for PV applications or paying for the data from a third-party solar provider. Customers can also have a better understanding of their individual PV systems with respect to their energy usage.
- **Environmental Benefits**
  - PV generation to customers allows them to understand the impact of their generation on their individual energy usage especially when combined with time of use metering and disaggregated load information. This could ultimately help customers be more efficient energy users.
- **Support of CPUC Proceedings or State Requirements**
  - R.14-08-013 Distribution Resources Plans
  - R.14-10-003 Integrated Distributed Energy Resources

Project 1.24 - Demonstrate Demand-Side Management (DSM) for Transmission and Distribution (T&D) Cost Reduction

This project successfully provided and tested the performance of a near real-time window of PG&E's Air Conditioning (AC) Direct Load Control (DLC) system, which utilizes one-way switch control devices. This allowed us to improve our ability to estimate AC DLC impacts at the distribution system level to better understand the localized impact of AC direct load control devices on meeting distribution feeder level reliability concerns. It also enabled near real-time visibility of AC direct load control installations to support Transmission and Distribution (T&D) Operations and provided Demand Response (DR) program administrators with near real-time feedback on any problems with direct load control devices before, during or after an event is called, which supports T&D operational improvements.

Benefits

- **Reliability**
  - Near real-time visibility into program performance advances a strategic objective to utilize DR resources not only to displace generation capacity, but also to support transmission and distribution grid reliability and improve performance of load control programs. This could be particularly important in the context of the increasing need to support renewables integration onto the distribution grid.
- **Economic Benefits**
  - The near real-time visibility and data collected by the data loggers can be used to reduce program operation costs and potentially reduce T&D infrastructure costs.
- **Adoption of EPIC Technology**
  - 586 data loggers were installed on or near the sampled outdoor A/C units in the project's target area. After project completion, the SmartAC Program continued to use the deployed data loggers to actively monitor program impact.
- **Support of CPUC Proceedings or State Requirements**
  - A.12-07-004 Demand Response (DR) Incentives
  - A.14-06-001 Demand Response (DR) Change in Tariff Rules

- R.13-09-011 Demand Response (DR)

Project 1.25 - Develop a Tool to Map the Preferred Locations for DC Fast Charging, Based on Traffic Patterns and PG&E's Distribution System, to Address EV Drivers' Needs While Reducing the Impact on PG&E's Distribution Grid

This project addressed Electric Vehicle (EV) adoption barriers by identifying optimal locations within PG&E's territory for the placement of DCFCs based on factors such as cost, available service transformer capacity, traffic patterns, as well as site host and driver preference. PG&E worked with industry experts to identify the 300 locations of highest unmet public charging need, forecasted out to 2025. Using a variety of inputs, including publicly-available business listing data, PG&E's distribution network to assess available distribution capacity, results from expert interviews, and PlugShare's database on existing public charging locations, the team then identified over 14,000 individual potential charger host sites, such as businesses, parking lots, and public places. The results of the project were developed into an interactive online map that visualizes the 300 optimal DCFC locations. The publicly-available map is accompanied by guidelines in the final report surrounding best practices for siting DCFCs developed to further encourage EV adoption by drivers, site hosts, and developers.

Benefits

- **Reliability**
  - By providing recommended site locations based on available transformer capacity, PG&E guided developers to install DCFCs in locations that would mitigate capacity overload or upgrades.
- **Economic Benefits**
  - The report identified distribution upgrades as a major cost driver for DCFC installers. Identifying site hosts with and without distribution capacity, assists in

saving the time and money from potential installers by identifying site hosts that have available capacity.

- **Environmental Benefits**
  - This project developed capabilities to support the deployment of charging infrastructure, which furthers the overarching goal of clean transportation.
- **Adoption of EPIC Technology**
  - The tools developed in this project helped enable PG&E to engage with OEMs and state stakeholders to help facilitate planning and siting of DCFCs. In addition to posting the interactive map on its EPIC website, PG&E has sent the siting tool to over 30 different external stakeholders upon request since project completion.
- **Support of CPUC Proceedings or State Requirements**
  - R.13-11-007 Alternative-Fueled Vehicles Programs
  - R.18-12-006 Development of Rates and Infrastructure for Vehicle Electrification (DRIVE)

EPIC 2 Project Benefits

Project 2.02 - Distributed Energy Resource Management System

This project provided an opportunity for PG&E to define and deploy a DERMS and supporting technology to uncover barriers and specify requirements to prepare for the increasing challenges and opportunities of DERs at scale. The DERMS Demo was a ground-breaking field demonstration of optimal control of a portfolio of 3rd party aggregated behind-the-meter (BTM) solar and energy storage and utility front-of-the-meter (FTM) energy storage to provide distribution capacity and voltage support services while also allowing for participation of these same DERs in the CAISO wholesale market.

Benefits

- **Safety**

- Better visibility into DERs on the grid will give the utility more confidence that any switching operation on circuits with DERs accounts properly for the contributions of DERs, better preserving safety in situations where the grid is abnormally switched.

- **Reliability**
  - While significant problems were experienced by PG&E because of DERs are relatively infrequent today (e.g. masked load, capacity and voltage violations, reverse power flow), DER penetration is expected to increase in the future and DERMS technology could address the associated increase in issues related to the planning and operation of an increasingly complex distribution grid.
- **Economic Benefit**
  - DERMS technology may allow PG&E to avoid costly upgrades and plan the grid more efficiently. DERMS technology may also enable DERs to be more effectively used for wholesale market participation, unlocking additional value streams for customers and optimizations for front-of-the-meter resources.
- **Environmental Benefits**
  - The development and deployment of a DERMS platform will enable the continued integration of renewables into the grid.
- **Adoption of EPIC Technology**
  - This project informed numerous foundational requirements around DER monitoring and communication within PG&E's 2020 General Rate Case (GRC), CH 19: Integrated Grid Platform Program and Grid Modernization Plan, specifically for Advanced DMA Platform and SCADA Replacement and Distribution GIS Asset Data Improvement investments. The learnings from this project also contributed to PG&E's successful EPIC 3.03 – *Distributed Energy Resource Management System (DERMS) and Advanced Distribution Management System (ADMS) Advanced Functionality* project.
- **Technology Development Progress**

- Through collaboration with the participating vendors, other PG&E demonstrations, and industry leaders to successfully demonstrate the potential of DERMS technology and achieve key learnings, the DERMS demonstration progressed the state of the industry.

- **Support of CPUC Proceedings or State Requirements**
    - The findings from the project have been used to support changes to telemetry requirements for DER interconnections under Rule 21 (R.17-07-007), and informed PG&E's participation in Rule 21 Working Groups 3 and 4, and the Smart Inverter Working Group.
    - R.11-09-011 Rule 21, Smart Inverter
    - R.14-10-003 Integrated Distributed Energy Resources

Project 2.03A - Test Smart Inverter Enhanced Capabilities – Photovoltaics (PV)

This project field-demonstrated commercial Smart Inverters (SIs) on a high photovoltaic (PV)-penetration distribution feeder, evaluated a vendor-agnostic SI aggregation platform, and lab-tested multiple SI models. The project established that there is significant potential for cost-effective local voltage support from SIs to help mitigate local secondary voltage challenges caused by high PV penetration. The learnings from this project have directly contributed to an enhanced understanding of the potential of Smart Inverters, and are valuable for distribution grid operations, electric generation interconnection, distribution planning, and customer programs.

Benefits

- **Reliability**
    - In its current form, today's grid—especially its distribution system—was neither designed nor equipped to accommodate such a high penetration of DER while sustaining high levels of electric quality and reliability. This project demonstrated

SI capabilities to improve grid reliability by mitigating the impact of renewable resources on secondary and primary system voltage.

- **Economic Benefit**
    - Conventional mitigation measures (transformer upgrades, reconductoring, additional voltage regulation equipment, etc.) provide a possible path towards accommodating more distribution-connected DER in PG&E's service territory. CPUC Electric Rule 21 mandating the use of SIs with autonomous functions provides new, alternative solutions that may perform equally well with potential for improved ratepayer benefits. Specific 2.03A activities that targeted cost reductions included 1) the evaluation of SI ability to help mitigate voltage problems resulting from high PV penetration on a distribution feeder and 2) the modeling study, which performed an economic analysis of SI capability vs. traditional grid upgrades across multiple PG&E distribution feeders and evaluated the potential to update PG&E standards for performing voltage rise studies when new BTM DERs are interconnected.
- **Environmental Benefits**
    - SIs can help to better integrate renewables, and, therefore, advance California energy policy to increase the amounts of renewable and distributed generation on the grid. By assessing SIs' ability to address DER-caused voltage issues through both the field demonstration and modeling, this project shed light on SIs' potential to increase hosting capacity, potentially allowing for faster and more affordable interconnection of additional DERs onto PG&E's distribution system. Additionally, lab testing activities evaluated SI responses to extreme grid conditions, which may result in updates to SI standards.
- **Adoption of EPIC Technology**
    - Provided insights and lessons about how to improve operations for the 2020 GRC, Chapter 19: Grid Modernization, specifically for Advanced DMA Platform and SCADA Replacement investments on distribution planning, interconnection enhancements, ADMS requirements, customer program(s) related to smart

inverters, as well as policies and contractual agreements for customers to allow PG&E to use/control their smart inverters in the service of power quality.

- **Support of CPUC Proceedings or State Requirements**
    - The findings from the project were used to support changes to telemetry requirements for DER interconnections under Rule 21 (R.17-07-007), and informed PG&E's participation in Rule 21 Working Groups 3 and 4, and the Smart Inverter Working Group.
    - R.11-09-011 Rule 21, Smart Inverter
    - R.14-10-003 Integrated Distributed Energy Resources
- **Informed Industry and/or Company Standards**
    - Findings from the project were actively used to inform and Institute of Electrical and Electronics Engineers (IEEE) Smart Inverter standards.

Project 2.03B - Test Smart Inverter Enhanced Capabilities – Vehicle to Home

This project assessed the technical feasibility and potential benefits to individual customers and to ratepayers of vehicle to home (V2H) technology which can be utilized for resiliency and reliability. This project showed that at the time, V2H was technically capable of islanding and supporting household load in outage and demand response events and customers reported high initial interest. However, the technology was not yet commercially available and vehicle warranties would have needed to be modified to allow for discharge, the cost to customers exceeded their perceived benefits, and the net benefits to the utility and ratepayers were likely not sufficient to surmount the low cost-effectiveness for customers. The V2H market was nascent at the time of this project and required further investigation ahead of PG&E commercialization activities.

Benefits

- **Safety**

- The project contributed to this principle by exploring and documenting the interconnection requirements for V2H technology ahead of broader commercialization. B-directional power flow-capable EVs were not commercially available in the United Sates at the time. The project showed that for V2H technology to become a mass market product, the automotive manufacturers would need to build EVs with these capabilities. Documenting these requirements would help inform market actors' understanding of safety considerations while pursing commercialization of the technology.

- **Reliability**
    - The project contributed to this principle by demonstrating technical feasibility at a proof-of-concept level that methods could be available to load serving entities for leveraging EVs to support DR activities during peak load and outage conditions.
- **Economic Benefits**
    - The project contributed to this principle by demonstrating the technical feasibility of V2H and validating the costs and benefits of the V2H technology at a directional, site-specific level to vet the potential commercial prospects of the technology before dedicating ratepayer funds to support commercialization. As this project helped to identify that V2H technology was not yet commercially viable at the time, PG&E estimated this project helped to avoid what could have been up to a $5.8M incentive program to spur V2H adoption at the time of the project.
- **Environmental Benefits**
    - V2H could maximize a customer's existing renewable generation (PV) by paring it with EV and potentially storage. These non-fossil fuel-based power generation technologies can facilitate reducing GHG emissions by offsetting any fossil fuel-based generation on PG&E's system.
- **Technology Development Progress**

- This project identified a set of key issues that needed to be addressed before V2H solutions could be commercialized.

- **Support of CPUC Proceedings or State Requirements**
    - R.18-12-006 Development of Rates and Infrastructure for Vehicle Electrification (DRIVE)
    - R.13-11-007 Alternative-Fueled Vehicles Programs
    - R.11-09-011 Rule 21, Smart Inverter

Project 2.04 - Distributed Generation Monitoring and Voltage Tracking

This project demonstrated an algorithmic process to analyze new data sources (including SmartMeter devices and databases of solar irradiance) to predict the likelihood that a Rule 2 voltage violation was caused by distributed solar generation. Solar energy is by nature intermittent, and ebbs and surges of generation can change the voltage for neighboring, downstream customers. As solar adoption continues to grow, there is an increased likelihood of such voltage violations. This functionality, if integrated into a larger grid analytics platform, might improve decision making for Power Quality Engineers responding to customer issues, and Distribution Planners as they work to support safe and reliable solar installation across PG&E's service territory.

Benefits

- **Reliability**
    - The results of this project can enable power quality, planning and operating engineers to better understand the likelihood that a voltage violation is caused by DG. For Power Quality, this potentially means faster response to customers. For Operating Engineers, this may save money by reducing the number of trouble man trips. For Planning Engineers, this may help make better DG siting decisions in the future.
- **Economic Benefits**

- The ability to identify the likelihood and location of voltage problems associated with PV installations has the potential to reduce the time and costs of investigating and resolving violations, because trips to the field to investigate the problem gather data and implement the final resolution are reduced. The predictive analysis may also have the potential to enable PG&E to anticipate and avoid future voltage violations related to DG.

- **Environmental Benefits**
  - Providing the ability identify the likelihood of whether PV installations will create voltage problems could identify areas capable of supporting additional PV installations. This supports PG&E's shifting energy procurement requirements towards renewable generation sources and reductions in GHG emissions.
- **Support of CPUC Proceedings or State Requirements**
  - R.14-08-013 Distribution Resources Plans

Project 2.05 - Inertia Response Emulation for DG Impact Improvement

As California pursues its objective of reducing carbon emissions of the power system, Pacific Gas and Electric Company (PG&E) is increasing the amounts of renewable generation in its generation resource mix. Conventional generation, such as gas fired plants, are machine-based, synchronous, rotating power generation resources and are being replaced by renewable generation, such as solar photovoltaic (PV) power plants and wind turbines, which are electronic and inverter-based resources. This generation technology shift decreases the total inertia of spinning mass connected to the grid, which is one property of the system that helps maintain stability during sudden disruptions, such as the loss of major generators. To compensate for future decreased inertia on the grid, this project investigated how to add "Synthetic Inertia" to maintain the reliability and robustness of a future renewable grid.

This project explored the capabilities of inverter-based energy resources to provide a set of functions related to system inertia which support the electric system. The project demonstrated via transmission system modeling and Power-Hardware-In-Loop testing that advanced inverter control methods can provide active power support that improves the system's frequency response in the face of reduced conventional inertia from synchronous machine generators. Inverter control methods were explored including inertia-like response (derivative control) and grid-forming (voltage source) modes for respective benefits in bulk system and isolated distribution system use cases.

Benefits

- **Reliability**
    - Transmission level modeling was created and used low-inertia scenarios to identify thresholds and conditions where system instability reaches a critical level. The threshold identified was an inverter-based penetration threshold of 57 percent. Before this project, the potential impact of inverter-based resources and low-inertia was virtually unknown.
- **Environmental Benefits**
    - Most renewable energy resources are inverter-based and this project enables more generation resources to interconnect to the grid. This will lower the GHG emissions, air pollution, and subsequent negative health impacts produced by the electricity sector.
- **Technology Development Progress**
    - The EPIC project team worked with a variety of stakeholders to share knowledge gained from this research including EPRI, WECC, NERC, NREL, and SCE.
    - In March 2019, NREL presented the findings on PG&E's behalf at the Energy Systems Integration Group (ESIG) meeting in regards to EPRI Program 173: Bulk System Integration of Renewables and Distributed Energy Resources.[54]
- **Adoption of EPIC Technology**
    - Provided insights and lessons about how to improve operations for 2020 GRC, Chapter 19: Grid Modernization, specifically for Electric Generation

54. https://www.epri.com/research/programs/067417.

Interconnection investments. It will potentially revise PG&E's interconnection standards for storage, PV, or other inverter-based generation, enhancing the definition of how to safely and reliability integrate these technologies onto the system.

- **Support of CPUC Proceedings or State Requirements**
    - R.11-09-011 Rule 21, Smart Inverter
    - R.17-07-007 Streamlining Interconnection of Distributed Energy Resources and Improvements to Rule 21
- **Informed Industry and/or Company Standards**
    - Learnings from this project informed IEEE Standard 2800 - Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems[55]
    - The findings from this project and IEEE 2800 will likely inform PG&E interconnection standards in the future.

Project 2.07 - Real Time Loading Data for Distribution Operations and Planning

This project developed analytical methods for generating near real-time load forecast information. The project successfully built and demonstrated a platform to ingest and process SmartMeter, Supervisory Control and Data Acquisition (SCADA), photovoltaic system (PV) generation, Geographic Information System (GIS) and weather data for two of the eight Areas of Responsibility (AOR) within PG&E's service territory.

Benefits

- **Safety**

55. https://standards.ieee.org/ieee/2800/10453/.

- Having look ahead visibility into dynamic grid load conditions will allow operators to better plan for maintenance and enhance operational decision-making awareness.

- **Reliability**
  - Providing forecasted load visibility to distribution engineers and operators to allow them to manage distribution switching for both planned and unplanned events more quickly and with less switching steps.
- **Economic Benefits**
  - Having accurate predictive load forecasts may reduce the number of switching steps required to perform maintenance and restoration and therefore reduce operational costs.
- **Adoption of EPIC Technology**
  - Provided insights and lessons about how to improve operations for 2020 GRC, Chapter 19: Grid Modernization, specifically for Advanced DMA Platform and SCADA Replacement investments.

Project 2.10 - Emergency Preparedness Modeling

The project developed and demonstrated a decision support system that successfully recommends optimal restoration and resource allocation strategies for PG&E electric assets after a disruptive event occurs.

Benefits

- **Safety**
  - This application will allow resources to respond to public safety incidents more rapidly. Deploying the appropriate number of resources to an event will allow safety personnel to rapidly address hazards like a downed wire or leaning pole.
- **Reliability**
  - Reduced restoration times leading to a more reliable electrical service: Accurate resource allocation recommendations in advance of an event will ensure that

logistics will provide the right amount of support, while mutual aid or contractors can be activated and transported to the optimal locations. These decisions require lead time, so timely analysis or forecasts will eliminate any delays associated with acquisition or decisions that need to be made due to a faulty analysis.

  - Enhance reliability using real-time information: The Emergency Operations Center (EOC) would have the ability to explore restoration strategies using real-time information to enhance reliability of the electric and gas systems. This project could enable PG&E to better quantify, in real-time, the impacts of events and the impacts of different restoration activities taken on power outages and costs.
  - This project has the potential to achieve reliability benefits by increasing PG&E's ability to model natural hazards and outage restorations. The tool can be agnostic to type of emergency (earthquake, flood, fire, tsunami, major storm, etc.). Benefits are multiplied because the tool has the potential to handle any type of major catastrophic event, and scale accordingly to the importance of the event.
- **Economic Benefits**
  - The optimization of restoration plan development can reduce cost by recommending the most efficient allocation of resources.

Project 2.14 - Automatically Map Phasing Information

This project successfully developed and demonstrated automated analytical methods for determining meter phasing and meter-to-transformer connectivity using SmartMeter, Supervisory Control and Data Acquisition (SCADA) and Geographic Information System (GIS) data. The distribution network model is central to multiple existing control systems, system analyses, and work processes. As the load characteristics of the distribution network evolve, such as with the growth of Distributed Energy Resources (DER), it is becoming more important to have accurate and up-to-date network model information to be able to actively manage the distribution system. Automated approaches for obtaining this information can offer a more efficient alternative to the conventional boots-on-the-ground approach.

Benefits

- **Increase Safety**
    - Phase identification is required for detailed understanding of network topology and complex power flows introduced by increasing DERs, to ensure safe operation of the system.
- **Improve Reliability**
    - Instability and reliability issues can result if one phase is significantly different in load than the other two. This project enables PG&E to better balance the loading on the 3 phases of the power delivered.
- **Reduce Costs**
    - These automated solutions developed in this project, if deployed across PG&E's entire service territory, would potentially provide around $9,000,000 in avoided cost savings and reduced customer bills compared to a PG&E-wide conventional "boots on the ground" phase identification effort.[56]
- **Environmental Benefits**
    - Better Phase ID can help accommodate the interconnection of renewable DERs. These non-fossil fuel-based power generation technologies can facilitate GHG emissions reduction by offsetting fossil fuel-based generation on PG&E's system.

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56. In the absence of analytical phase identification methods, manually verifying phase information would likely need to be performed on the majority of circuits. Assuming 70 percent of circuits of PG&E's 2,500 circuits would need to be verified, at a cost of $7,000 per circuit, avoiding this by instead applying analytical methods would result in a cost savings of approximately $12M. The most successful analytical method demonstrated in 2.14, which would be used in production, was developed by PG&E within the EPIC project. However, to account for follow-on improvements made to the analytical method after the EPIC project and before operational deployment, a 75 percent attribution factor is applied, which results in $9M benefits attribution to EPIC 2.14.

- **Adoption of EPIC Technology**
    - The full-scale deployment of this project's solutions was included in PG&E's 2020 GRC, CH 19: Integrated Grid Platform Program and Grid Modernization Plan.
- **Support of CPUC Proceedings or State Requirements**
    - R.14-08-013 Distribution Resources Plans

Quantitative Benefits Summary

Benefit Area	Measurement
Economic Benefits	$9,000,000

Project 2.15 - Synchrophasor Applications for Generator Dynamic Model Validation

This project installed Phasor Measurement Units (PMUs) on the three generators at PG&E's Colusa Generation Station, developed station generator models using commercial software, and used actual disturbance data collected online (in lieu of offline test data) to test new synchrophasor applications for generator model validation. The integration of PMUs on generators for dynamic model validation is a new technology and the project did not result in a tool that is production ready. As applications evolve, installation of PMUs at generating stations could potentially allow utilities to enhance their generator model validation processes.

Benefits

- **Reliability**
    - The project demonstrated the use of synchrophasors and associated software tools to perform parameter estimation for generator dynamic models remotely using collected disturbance data. Current processes require testing at the power plant. More accurate generator models would result in more accurate grid reliability studies. The tool and methodology tested did not conclusively demonstrate that it could be replace current test methods based on the reasons covered in the final report.

- **Economic Benefits**
    - The collection and use of synchrophasor data, to perform NERC-mandated generator dynamic model calibration, potentially reduces the need to perform tests at the power plants. This could reduce costs and is an efficient use of ratepayer monies. As noted in the final report, the cost savings was not proven sufficient to justify the cost of installing generator PMUs.
- **Adoption of EPIC Technology**
    - Provided insights and lessons about how to improve operations for 2020 GRC, Chapter 4: Hydro Operations Costs.

Project 2.19 - Enable Distributed Demand-Side Strategies & Technologies

This project evaluated the performance and efficacy of using customer-sited behind-the-meter storage for grid and reliability services. The project utilized both residential and commercial assets via two vendor platforms. The project showed that BTM energy storage is technically feasible for the use cases evaluated, and also identified opportunities for improvement to inform broader application of these use cases.

Benefits

- **Reliability**
    - This project explored the use of customer-sited behind-the-meter storage to respond to instructions to charge during times of maximum solar output and discharge during the later afternoon net load ramp when solar output is declining, an application of the technology which could contribute to grid reliability. In addition, the project investigated the dual-use of customer-owned storage to provide back-up power for individual customers.
- **Economic Benefits**

- This project explored the use of customer-sited BTM energy storage to provide commercial customers with opportunities to lower their cost of energy via peak load shaving to avoid demand charges, while also executing directions to charge during times of maximum solar output and discharge during the later afternoon net load ramp when solar output is declining.

- **Environmental Benefits**
  - In addition to testing the ability of customer-sited storage systems to absorb system solar power, this project also explored the use of residential storage co-located with solar PV systems to charge the batteries exclusively using solar power. Both applications of customer-sited energy storage can help better integrate renewables.
- **Adoption of EPIC Technology**
  - Provided insights and lessons about how to improve operations for 2020 GRC, Chapter 19: Grid Modernization, specifically for Advanced DMA Platform and SCADA Replacement investments.
- **Support of CPUC Proceedings or State Requirements**
  - R.14-10-003 Integrated Distributed Energy Resources

Project 2.21 - Home Area Network (HAN) for Commercial Customers

This project demonstrated the viability and usefulness of access to real-time energy use data for commercial customers. This technology demonstration accomplished three set objectives: 1) verified Zigbee enabled SmartMeters for Large Commercial and Industrial customers have the same ability as residential meters to provide real-time usage information via the HAN radio; 2) Identified and assessed LC&I customers' needs and meaningful use cases (i.e. opportunities) for real-time data; 3) Identified the barriers to adoption, integration, and utilization of HAN devices at scale for LC&I customers.

Benefits

- **Economic Benefits**

- The project aimed to provide affordability benefits to customers by providing real-time AMI data to customer for Demand-Side Management (DSM). The technology presented in this project has the potential to offer an affordable option to maximize DSM if and when site installation requirements are met. Benefits will vary by customer. Some sites required modification or adaption to implement real-time data feeds, while other sites required a greater investment in time and resources to integrate the data into their EMS. The greatest benefits are likely to accrue where multiple locations are under a single EMS.

- **Environmental Benefits**
  - This project has shown real-time data directly enabled intervention actions related to quick PV system failure detection and recovery, and modification to DR strategy during DR event period. These interventions can lead to reduction in GHG gas emissions through lower energy usage and increase up-time of renewable energy resources.

Project 2.22 - Demand Reduction through Targeted Data Analytics

This project developed a tool that leverages customer level data along with grid information and forecasts to create a robust optimization engine for identification of the lowest cost solution capable of deferring or mitigating the need for an asset upgrade due to capacity limitations. The tool considers both traditional wires solutions and DER portfolios and allows Distribution Planners to complete advanced scenario analysis.

Benefits

- **Reliability**
  - The tool demonstrated in this project allows us to reduce the need to make equipment replacements and therefore reduce planned and unplanned outages.
- **Economic Benefits**
  - The tool developed in this project has the potential to significantly improve the efficiency and effectiveness of PG&E's distribution planning process going

forward. The total annual benefit of the application of the optimization tool associated with 1) the identification and deferral of distribution capacity upgrades and 2) improvements in process efficiency.

- **Environmental Benefits**
  - The DER portfolios recommended by the tool demonstrated in this project reduce load requirements for the utility and therefore associated GHG emissions.
- **Adoption of EPIC Technology**
  - This project provided insights and lessons about how to improve operations for 2020 GRC, Chapter 19: Grid Modernization, specifically for Distribution Engineering Planning Tools investments and will be scaled up to support PG&E's advancing distribution planning processes through optimized location-specific targeting to leverage cost-effective, non-wires alternatives based on grid needs. The tool developed through this EPIC project has already been applied to the annual Distribution Deferral Opportunity Report (DDOR) and is expected to significantly improve the efficiency and effectiveness of PG&E's distribution planning process going forward.
- **Support of CPUC Proceedings or State Requirements**
  - R.14-08-013 Distribution Resources Plans
  - R.14-10-003 Integrated Distributed Energy Resources

Project 2.23 - Demand Side Utility Planning

This project successfully developed and demonstrated the integration of a broader range of customer-side technologies and Distributed Energy Resources (DER) approaches into the utility planning process. The project served as a necessary and enabling precursor to the fulfillment of Assembly Bill (AB) 327/ Section 769, which requires transparent, consistent and more accurate methods to cost-effectively integrate DERs into the distribution planning process. This project delivered new load shape profiles, enhanced load forecasting tool and overall analytical process that allows PG&E to more accurately and consistently integrate DER impact to the distribution system load profile. With these enhancements, PG&E can evaluate if DER growth could defer or even in some instances eliminate the need for future network upgrades. Leveraging any of the SmartMeter data, PG&E created more accurate and granular load shapes that allowed distribution planners to more precisely capture DER impact on the load growth forecast.

Benefits

- **Safety**
    - By hierarchically aggregating load shapes, PG&E engineers can leverage load forecasts to project the timeframe when power flow could reverse at certain distribution system components (e.g. voltage regulators, protective devices) that are not presently designed to operate under such conditions. The reverse power flow could create a safety concern, as equipment may be more likely to fail. With prior knowledge of such a condition possibly existing, PG&E planners could potentially address the problem and eliminate the safety concern.
- **Reliability**
    - The project leveraged SmartMeter data to generate more accurate load shapes and DER adjustment forecasts at the system and granular (customer) level. With more accurate representation of load and DER adoption, distribution engineers can better model current and future grid conditions. Consequently, the system simulation results will more accurately represent the direction and magnitude of power flows. Recommended infrastructure modifications, and equipment specifications and settings can therefore better match the actual conditions, improving the reliability of the system. This enhancement supports the ability to decrease overloads, of which wear on the system components inherently increases risk of outages.
- **Economic Benefits**
    - The ability to include DER adjustment forecast in an integrated least-cost planning framework will potentially result in lower system costs, by avoiding system upgrades where load growth will be offset with DER adoption. By having

the ability to analyze the DER profile impact on the overall load shape, PG&E will be able to potentially target certain DER programs that have the shape and magnitude appropriate to defer or eliminate network upgrades

- **Environmental Benefits**
    - This project can potentially reduce GHGs by helping to identify additional opportunities for distribution connected renewable generation.
- **Adoption of EPIC Technology**
    - This project provided insights and lessons about how to improve operations for 2020 GRC, Chapter 19: Grid Modernization, specifically for Distribution Engineering Planning Tools investments to ensure that DER forecasts are incorporated in PG&E's planning process. The improved load forecasting capabilities developed in this project have been transitioned to operational use in support of the distribution planning process.
- **Support of CPUC Proceedings or State Requirements**
    - R.14-08-013 Distribution Resources Plans
    - R.14-10-003 Integrated Distributed Energy Resources

Project 2.26 - Customer and Distribution Automation Open Architecture Devices

PG&E's AMI Network is one of the largest private Internet Protocol Version 6 (IPv6) networks in the Unites States, with more than 5 million AMI devices connected across its electric network. This project investigated the use of the AMI network for purposes beyond the collection of electricity usage data. The project successfully demonstrated the ability of a Client-Server architecture consisting of an IoT router to establish communication, monitoring, command, and control of various third-party and utility end devices such as smart inverters, sensors, SCADA devices, RFID readers and distributed generation controls over the AMI network using the IEEE 2030.5 protocol.

Benefits

- **Reliability**
  - This project demonstrated the potential to use the AMI (mesh) network for communicating with SCADA and other electric distribution energy devices. A mesh network is more reliable than a non-mesh network because when one node is inoperable, other nodes can still communicate with each other directly or through intermediate nodes.
- **Economic Benefits**
  - The AMI-based RFID tracking capability for meter inventory management and asset identification showed the potential to reduce inventory costs.
- **Adoption of EPIC Technology**
  - The AMI-based RFID tracking capability for meter inventory management and asset identification has been funded through the GRC and is planned to be deployed.

Project 2.27 - Next Generation Integrated Smart Grid Network Management

This project demonstrated a new AMI Network management system (a "manager of managers") to holistically and more effectively monitor, control, and evolve the existing AMI network and infrastructure. Currently, PG&E leverages multiple AMI networks with separate operational systems. Leveraging disparate systems limits the ability to optimally manage workflow and prioritize and schedule data processes (for instance, ensuring remote connect/disconnect is prioritized over tenant application queries).

Benefits

- **Safety**
  - The automation of processes demonstrated through this project to identify and notify technicians of potentially hazardous conditions related to meter

temperature, incorrect meter-wiring, or energy diversion could allow for these conditions to be identified sooner and resolved faster than is possible through current manual processes.

- **Reliability**
  - The aggregation of data across PG&E's three AMI networks into a single management platform contributes to overall SmartMeter network reliability by providing, on a real-time basis, a high-level view of identified problems and then allowing for a quick drill down for evaluation and when appropriate, automatically generating and tracking follow-up work orders. Reliability of the SmartMeter network contributes to overall grid reliability by providing visibility to problems and enablement of troubleshooting in real time.
- **Economic Benefits**
  - The more efficient diagnosis of problems through process automation demonstrated through this project has the potential to reduce labor costs. This project demonstrated the ability to quickly narrow the problem area to provide improved information on when and what type of personnel to dispatch to resolve an issue. In addition, by quickly resolving issues such as high temperature sockets, equipment damage and replacement can be avoided.
- **Adoption of EPIC Technology**
  - Provided insights and lessons about how to improve operations for 2020 GRC, Chapter 8: Information Technology.

Project 2.28 - Smart Grid Communications Path Monitoring

This project sought to 1) Conduct an initial noise assessment to establish a baseline of radio frequency interference (RFI) in the AMI Networks, 2) Analyze a continuous flow of data to identify potential locations and sources of RFI, and 3) Develop an end-to-end process/tool from monitoring to mitigation of interference. PG&E identified through a sample of radio frequency (RF) data that there are potential channel congestion issues that can lead to RFI conflicts in the

AMI networks, however no specific RF tools existed to identify RFI signal(s) in PG&E's local Neighborhood Area Network (NAN). Given the RF dataset availability and access limitations, there was no feasible path to demonstrate a successful algorithm-based application for proactive automated interference detection. The preliminary work completed on this project could be leveraged in the development and/or use of future tools and in formulation of strategies around broader prevention of PG&E's network RFI.

Benefits

- **Economic Benefits**
    - Given the significant data access limitations encountered early in this project, there was no feasible path forward for the project team to demonstrate a successful algorithm-based application for proactive automated interference detection. Although a small sample of channel loading data was obtained for a small test area in San Francisco, the lack of continuous data points and resolution of this information restricted algorithm development and the ability to execute a complete end-to-end RFI solution. As such, PG&E made an early decision to discontinue the project and avoid any unnecessary further expenditures towards the project.

Project 2.29 - Mobile Meter Applications

This project designed, built, and tested the Next Generation Meter (NGM). This electricity meter was demonstrated to be the first revenue grade, high-resolution real-time power meter that fully met national standards for metering including ANSI C12.1 and ANSI C12.20 (accuracy), ANSI C12.19 (meter data table format) and C12.22 (cellular communication protocol format). The NGM was developed with a compact, modular design that takes advantage of a host of new technologies including faster microprocessors, expanded memory, and multiple communications pathways—all contained in a hardware package that is the size of a credit card. The NGM has the ability to: 1) Be installed in a wider range of locations beyond traditional customer premises, 2) Reduce meter maintenance and replacements costs, 3) Improve the grid operator's situational awareness during outages, and 4) Provide additional services and applications as grid-edge technology evolves.

Benefits

- **Safety**
    - The design of NGM separates high and low voltage metering components of a SmartMeter. This separation reduces the exposure of field technicians to high voltages during maintenance and repair of meters.
- **Economic Benefits**
    - The design of the NGM modularizes meter components by separating high and low voltage components, which can significantly reduce both maintenance and operating costs. This provides the flexibility to replace only failed components, as opposed to the entire meter when one component fails.
- **Environmental Benefits**
    - The NGM will have the capability to consolidate metering of EV's energy usage/charges at public locations/stations, or at home. This will enhance EV ownership and encourage the use of low-emission vehicles.
- **Adoption of EPIC Technology**
    - This project is the predecessor to EPIC 3.27, which is developing a revenue-grade EV submeter, in support of several proceedings.
- **Support of CPUC Proceedings or State Requirements**
    - R.14-08-013 Distribution Resources Plan
    - R.09-08-009 Alternative-Fueled Vehicle
    - R.13-11-007 Alternative-Fueled Vehicles Programs
    - R.18-12-006 Vehicle Electrification Rates and Infrastructure
    - CPUC Draft Transportation Electrification Framework

Project 2.34 - Predictive Risk Identification with Radio Frequency (RF) Added to Line Sensors

This project investigated the use of radio frequency-based Distribution Reliability Line Monitor (DRLM) and Early Fault Detection (EFD) technologies and compared their performance with Distribution Fault Anticipation (DFA) technology for predictive maintenance and risk reduction on electric distribution circuits. The demonstration successfully detected, located, and addressed multiple examples of conductor damage, vegetative encroachment, internal transformer discharge, fault induced conductor slap, and insulator and clamp issues. The project concluded that effective grid asset health and performance monitoring can be achieved through an ensemble approach and further work is necessary to improve and integrate sensor technologies into an analytics platform or Distribution Management System (DMS).

Benefits

- **Safety**
  - EFD's RF network monitoring offers to reduce the rate of occurrence of many classes of network faults that are known wildfire risks in California and globally. The technology predicts powerline fire risks ranging from vegetation encroachment to conductor (and conductor clamp) failure. Its predictive identification of risks allows them to be addressed proactively before they materialize.
- **Reliability**
  - EFD offers to reduce the number of network faults caused by deteriorated, damaged and compromised electricity network assets. The risks predictively identified in the demonstration were all known to be common causes of faults on PG&E's electricity distribution and transmission networks - faults that can and do regularly lead to interruptions to customer supply. Early warning of these risks can prevent the associated supply interruptions, thereby increasing supply reliability.
- **Economic Benefits**

- Cost savings associated with the deployment of EFD will result from the difference between repair to deteriorating or damaged equipment under normal schedule operating conditions instead of emergency conditions. If hazardous asset conditions are allowed develop to faults and asset failure, there is additional damage to asset infrastructure through the wear and tear of faults, as well as collateral damage to equipment near the fault, and greater labor costs to address these situations. Additional operational performance savings, such as reduction in system losses, would be achieved through the validation of correct operations of field equipment. Deployment of the EFD sensors demonstrated through this project on 75 additional feeders is now underway and is estimated result in around $6,000,000[57] in annual savings attributed to this EPIC project through reduced operating costs.

- **Adoption of EPIC Technology**
  - The EFD sensors from this project were transitioned to production at the project's limited demonstration sites, and a broader effort is underway to deploy EFD to 75 additional distribution circuits in high fire threat districts using GRC funds.
- **Technology Development Progress**

57. Calculation assumes a total of $160,000 of reduced operating costs per feeder per year. This savings is attributed to 1) Reduced overtime and double-time maintenance ($40,000), 2) Reduced DCC mobilization ($20,000), 3) Reduced lost workdays due to rest periods ($25,000), 4) Reduced collateral facility damage ($50,000), and 5) Reduced customer claims ($25,000). The technology will be deployed on a total of 75 feeders over the next four years. Multiplying $160,000 savings/feeder/year by 75 feeders results in savings of $12,000,000/year at full deployment. While this EFD technology would likely not have been adopted had it not been demonstrated through EPIC first, it was already deployed at a limited scale outside the United States, and as such, 50 percent of the expected annual benefits to PG&E are attributed to the EPIC project. Applying the attribution factor results in a savings of $6,000,000/year attributed to EPICI 2.34.

    - Through course of the demonstration, the project team gave the vendors of the technologies being demonstrated extensive feedback that is being incorporated into improved versions of their sensor solutions.
- **Support of CPUC Proceedings or State Requirements**
    - R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans

Quantitative Benefits Summary

Benefit Area	**Measurement**
Economic Benefits	$6,000,000/year

Project 2.36 - Dynamic Rate Design Tool

This project designed and developed a tool that leverages advanced technologies to allow for the rapid evaluation of rate designs, new billing determinants, and enables a more robust, powerful, and rapid bill impact analysis process than the current models allow.

Benefits

- **Economic Benefits**
    - Using the rate design tool would enable employees to run analyses faster. The tool would enable employees to be more efficient and focus more on innovative rate design and evaluation.
- **Environmental Benefits**
    - Using the rate design tool developed through this project would lead to a reduction in errors in the rate design and evaluation processes by eliminating manual transfer of inputs and outputs.

EPIC 3 Project Benefits

Project 3.03 - Distributed Energy Resource Management System (DERMS) and Advanced Distribution Management System (ADMS) Advanced Functionality

This project has developed the foundation of a scalable enterprise distributed energy resource management system (DERMS) platform that can communicate with non-SCADA distributed energy resources (DERs) and manage distribution needs and constraints to safely, reliably, and cost-effectively incorporate DERs into distribution grid operations. The primary deliverable of this project has been the establishment of a production-ready cybersecure DER head-end platform in IEEE 2030.5 communications standards to allow for customers to cost-effectively send telemetry data from their DERs back to PG&E. The development of this head-end system provides an effective means for customers with DERs over 1MW to comply with CPUC telemetry requirements established in Resolution E-5038, and provides the foundation for more advanced future DERMS coordination and control capabilities for a wide range of use cases.

Benefits

- **Safety**
  - Improves the safety of operating DERs by allowing distribution operators enhanced situational awareness for DERs that are supporting the grid.
- **Reliability**
  - Enables the ability to dispatch registration data requests to verify compliance of Smart Inverters (SI) with Rule 21 and monitor SI-based DERs to maintain safe and reliable grid operations.
  - Providing distribution operators enhanced situational awareness of DERs will help PG&E manage demand and capacity and avoid outages.
- **Economic Benefits**

- The CPUC now requires that all customers with DERs over 1MW provide telemetry data back to PG&E. The low-cost telemetry solution developed through this project has been transitioned into a production state with customers already being connected. It is conservatively estimated to save customers a total of $2,250,000/year[58] by providing them an alternative to using a recloser or mini-RTU to meet the telemetry requirement.

- **Adoption of EPIC Technology**
  - Per the commitment made through the Smart Inverter Working Group, the low-cost telemetry developed and demonstrated through this EPIC project has been transitioned into production in June of 2022, and four customers have already been connected
- **Support of CPUC Proceedings or State Requirements**
  - R.14-08-013 Distribution Resources Plan
  - R.14-10-003 Integrated Distributed Energy Resources
  - R.16-02-007 Integrated Resource Plan
  - R.11-09-011 Rule 21, Smart Inverter
  - R.17-07-007 Streamlining Interconnection of DERs and Improvements to Rule 21
  - R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans R.19-09-009 Microgrids Pursuant to Senate Bill 1339 and Resiliency Strategies
- **Informed Industry and/or Company Standards**
  - As PG&E continues to gain experience and lessons learned through the development of the DERMS EPIC 3.03 project, PG&E will work to address any

58. It is estimated that each customer will save approximately $90,000 by using PG&E's system instead of the alternative of using a recloser or mini-RTU, and that approximately 25 customers per year will connect and provide telemetry through PG&E's head-end system. It is further assumed that these benefits are 100 percent attributed to the EPIC 3.03 project, as it is unlikely that the market would have provided a viable solution had it not been for this EPIC project, and the output of the project is a system that has been transitioned directly into production. Total resulting customer savings attributed to EPIC 3.03 is $2,250,000/year.

gaps found in CSIP, IEEE 2030.5, Sunspec, and relevant cybersecurity standards via collaboration with the Smart Inverter Working Group, other CA Utilities, industry, and standards bodies.

Quantitative Benefits Summary

Benefit Area	Measurement
Economic Benefits	$2,250,000/year

Project 3.11 - Multi-Customer Microgrid for Enhanced Reliability & Resilience: Arcata-Eureka Airport

Through this project, PG&E worked with several partners, including the CEC, to establish the first multi-customer microgrid in PG&E's service territory at the Arcata-Eureka airport, and configure the local microgrid controller to integrate with PG&E's distribution network and enable Distribution Control Center visibility and control of the microgrid. The project developed scalable and replicable approaches to planning, designing, deploying, and operating multi-customer microgrids that will be essential to enabling the broader implementation of multi-customer microgrids going forward. The project also helped to inform the CPUC's microgrid proceeding, and defined the tariff structure and interconnection process of PG&E's broader Community Microgrid Enablement Program (CMEP).

Benefits

- **Safety**
    - EPIC 3.11 helped PG&E establish protocols for linemen safety and informed how they should interact with microgrids. Safety materials such as bulletins, job aids, and training for distribution operators were created.
    - The project team is using the lessons to develop a microgrid island study which will analyze the performance and operational safety of a microgrid.
    - Public safety benefits from this project as it ensures critical facilities remain energized. These critical facilities are the Redwood Coast Airport which supports

Life Flight which supports organ donation as well as the US Coast Guard which has saved dozens of lives in the past year.

- **Reliability**
    - This project enhances resilience and prevents outages due to PSPS, EPSS, car poles, end of the line, tsunami, fire, etc. The Arcata RCAM microgrid was specifically proposed due to tsunami risk and the learnings at RCAM have helped PG&E understand how to implement microgrids to other areas of the grid where outages from other causes are more common.
    - Two reliability microgrid programs have been heavily influenced by the Arcata RCAM project: the Community Microgrid Enablement Program (CMEP) and the Microgrid Incentive Program (MIP). After four years, these programs will likely result in a dozen microgrids, and this will result in an estimated reliability improvement of 160,000 CMI per year.[59]
- **Economic Benefits**
    - After four years of CMEP and MIP program implementation, the economic benefits due to the reduced outage time is estimated to be $3.9 million per year going forward.[60]
- **Environmental Benefits**
    - The addition of solar and battery energy storage systems in the microgrid will reduce the use of diesel generators during power outages.
- **Technology Development Progress**

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59. Assuming 12 microgrids are built over the next four years, a microgrid uptime during outage of 95 percent, 20 non-residential customers per microgrid, and an average annual outage minutes per customer of 1,298 (from the worst performing circuits), and a 50 percent benefits attribution to EPIC 3.11, this results in a reduction of 160,000 CMI per year attributed to EPIC 3.11.

60. This assumes the previously calculated reliability benefits of 160,000 CMI per year are applied to a non-residential outage multiplier of $25.10 per customer-minute. This value is from the ICE calculator (https://icecalculator.com/home) with only non-residential customers added to the inputs.

- The Redwood Coast Airport Microgrid has served as a model for the deployment of other microgrids in the state of California and beyond, helping to establish hardware, software, communications, and tariffs requirements. The project has directly informed the design of PG&E's CMEP and MIP programs.
- The project team worked with vendors to establish control schemes which allows PG&E's microgrid controller and the generation controller to interact and work together. To PG&E's knowledge, this has not been done before and the controls manufacturer had not done this before, so this informed the manufacturer's approach to implementing this technology.
- The project team influenced the vendor's battery system. PG&E saw a difference from the stated battery specifications and what was observed in the lab testing. This was brough to the battery vendor's attention and the specification was changed to reflect the lab testing results.

- **Support of CPUC Proceedings or State Requirements**
  - R.14-08-013 Distribution Resources Plan
  - R.11-10-023 Distribution Resource Adequacy
  - R.14-10-003 Integrated Distributed Energy Resources
  - R.16-02-007 Integrated Resource Plan
  - R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans R.19-09-009 Microgrids Pursuant to Senate Bill 1339 and Resiliency Strategies
  - R.15-03-011 Energy Storage Procurement Program
- **Informed Industry and/or Company Standards**
  - This project will inform the microgrid island study template which is under development.
  - The project helped define a microgrid architecture that works with PG&E policy and the technical capabilities that currently exist. Before this project, microgrids like this would have conflicted with company policy. This project will pioneer industry standards for replicable processes for the provisioning of local multi-

customer microgrid controllers, and for the communication and controls between those controllers and the larger grid.

  - The project informed a set of guidelines that equipment must meet in order to be a part of the community microgrid. There are currently a set of requirements for now, and although there are no standards yet, these requirements will likely become standards in the future.
  - This project directly informed the tariff structure and interconnection process of PG&E's CMEP.

Quantitative Benefits Summary

Benefit Area	Measurement
Increased Reliability	160,000 CMI/year avoided
Economic Benefits	$3,900,000/year

Project 3.11B - Location-Specific Options for Reliability and/or Resilience Upgrades

This project is in its early stages and will investigate if behind-the-meter (BTM) DERs can reduce the environmental and customer impacts of Public Safety Power Shutoff (PSPS) by being accommodated (not curtailed), enabled and/or relied on in microgrids. Using BTM DERs owned by third parties, combined with utility owned generation, and battery resources, this technology has the potential to reduce the outage time and diesel generation emissions related to PSPS.

Benefits

- **Safety**
  - This project will ensure that BTM DERs can operate safely during PSPS events.
- **Reliability**
  - This project reduces the impact of PSPS events on customer's energy access.
- **Economic Benefits**

- During PSPS events, this project would save on diesel costs for backup generation as well as avoiding economic costs due to an outage.

- **Support of CPUC Proceedings or State Requirements**
  - Senate Bill 1339 and the CPUC Microgrid Order Instituting Rulemaking (OIR)

Project 3.13 - Overhead Transformer Monitoring

This project will install and test pre-commercial overhead transformer temperature sensors on operational transformers in the field. Temperature data, and other available telemetry data, will be manually downloaded from the third-party vendor's server. The project will develop analytical models for analyzing temperature data, with other available data elements, such as load data and weather data. The objective of the data model will be to predict incipient/impending transformer failure.

Benefits

- **Safety**
  - Certain transformer failures can cause customer outages and potentially even fires. This project will allow for more proactive identification and mitigation of these risks.
  - Eliminating catastrophic failure limits possibility of Serious Injury/Fatality (SIF) Incidents, Notice of Violations (NOVs) and corresponding resources that need to be allocated to SIF and NOV cases.
- **Economic Benefits**
  - Proactively addressing issues allows for straight time charging vs. overtime charging. Enables estimating teams and field crews to perform planned work procedures (such as pole loading calculations and sizing the transformer for peak load conditions) rather than performing emergency, unplanned work and installing like-for-like size transformers in emergency situations.
- **Support of CPUC Proceedings or State Requirements**

- R.08-11-005 Decision adopting regulations to reduce fire hazards associated with overhead electric utility facilities and aerial communications facilities
- R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans Pursuant to Senate Bill 901 (2018)

Project 3.15 - Proactive Wires Down Mitigation - Rapid Earth Fault Current Limiter (REFCL)

This project is demonstrating Rapid Earth Fault Current Limiter (REFCL) technology at a PG&E substation serving a high fire-risk area, to assess its effectiveness at automatic current reduction in wires-down events, with the goal of drastically reducing the likelihood of wires down events causing wildfires.

Benefits

- **Safety**
  - Over the course of this demonstration, this promising REFCL solution has met or exceeded performance metrics for how fast it reduces current during faults and has the potential to reduce the number of ignitions from wires-down events on the 12kV distribution circuits in PG&E's High Fire Threat Districts by over 59 percent.
- **Reliability**
  - REFCL could improve reliability over the operating practice of proactively de-energizing circuits during high fire risk events. This project could also improve reliability by riding through transient faults.
- **Economic Benefit**
  - Using REFCL to reduce the likelihood of ignition in turn reduces the likelihood of catastrophic wildfires and the associated financial impacts of those fires.
- **Technology Development Progress**

    - PG&E has worked with the vendors that provide REFCL technology components to configure their product offerings for deployment on United States power grids, as previously REFCL has only been deployed by utilities overseas.
- **Adoption of EPIC Technology**
    - Pending successful completion of the demonstration, broader deployment of the REFCL solution is planned for additional substations in high fire thread districts through the GRC.
- **Support of CPUC Proceedings or State Requirements**
    - R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans
- **Informed Industry and/or Company Standards**
    - This demonstration will inform the deployment of other REFCL systems on California's electric grid, standardizing requirements for design, construction, and performance.

Quantitative Benefits Summary

Benefit Area	Measurement
Safety	59 percent[61] reduction in ignitions

Project 3.20 - Data Analytics for Predictive Maintenance

The core objective of EPIC 3.20 was to determine if machine learning models can be developed using existing utility data sets (such as AMI i.e. smart meters, asset location, and or weather data) to predict electric distribution equipment failures and outages, so that corrective action

61. The project has the potential of reducing the risk of electrical ignition events by 59 percent (based on statistics of fault type for electrical ignition events from February 2013 to April 2018). Calculation performed by PG&E's Applied Technical Services group and documented in the EPIC 3.15 - *Proactive Wires Down Mitigation - Rapid Earth Fault Current Limiter (REFCL)* business plan.

can be taken before either occurs. The project aimed to improve system reliability and safety by reducing unplanned outages by proactively identifying and mitigating equipment failure.

The project developed an industry leading analytical model for predicting issues with distribution transformers. Over 270 model predictions have been made so far, from which 62 percent were confirmed to be relevant transformer anomalies (a prediction success) and were flagged for field investigation. An additional 27 percent were confirmed to be other legitimate issues in the distribution system. On multiple occasions, near failing distribution transformers and meters have already been proactively replaced based on the model's recommendations.

Benefits

- **Safety**
  - Prediction of equipment requiring maintenance may potentially reduce public exposure to hazardous catastrophic equipment failure and reduce wildfire risk.
- **Reliability**
  - Predictive equipment maintenance reduces unscheduled outages caused by failed equipment. It is estimated that the technology prevents unscheduled outages by 1.2 million CMI per year.[62]
- **Economic Benefits**
  - Predicting that line equipment will require maintenance means that maintenance can be scheduled within normal operating workflow and avoid expensive unscheduled maintenance. Permitting targeted inspections as

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62. The reliability benefits assumes 100 interventions annually going forward (SME estimate), 13,274 customer outage minutes per distribution transformer failure (PG&E ILIS outage info), and that 90 percent of the interventions would eventually lead to transformer failure and an unscheduled outage and not been detected and prevented by other means. This results in a reduction of customer minutes of interruption of 1.2 million customer-minutes per year. The calculation further assumes an attribution of 100 percent to the EPIC 3.20 project because the transformer model was built from the ground up within the EPIC project, no comparable products are offered by vendors, and the tool has been transitioned directly into post-EPIC operation.

opposed to periodic inspections will better optimize field resources. Improved equipment operation will help optimize system performance.
    - The reliability benefits of 1.2 million CMI per year results in an economic benefit to customers of $3.2M per year.[63]
- **Technology Development Progress**
    - The overarching data science techniques are planned to be shared with the industry to enable broader market innovation around data-driven prediction of asset failure and maintenance needs.
- **Adoption of EPIC Technology**
    - Upon successful demonstration the software tool has been transitioned to continued use in production.
- **Support of CPUC Proceedings or State Requirements**
    - R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans

Quantitative Benefits Summary

Benefit Area	Measurement
Reliability	1.2 million CMI/year avoided
Economic Benefits	$3,200,000/year

Project 3.27 - Multi-Purpose Meter

This project leveraged the Next Generation Meter (NGM) developed in EPIC 2.29 to develop a utility-grade electric vehicle and EV charging submeter prototype that can be easily plugged into readily available level 2 and emerging level 3 EV charge stations. PG&E, the other California Utilities and industry influencers will update the EV submetering standard for CPUC adoption.

63. Using the CMI previously calculated as 1.2 million CMI per year and assuming a multiplier of $2.69 per customer-minute, the cost reduction is $3.2 million per year.

Benefits

- **Safety**
  - The separation of high and low voltage components enables the NGM core to be incorporated into EV chargers for easy and safe installation without exposure to high voltage hazards.
- **Reliability**
  - This EV meter will allow for non-traditional meter installations to obtain granular data (voltage, current, temperature, etc.) which enables monitoring capability and visibility.
- **Economic Benefits**
  - Reduced meter asset material and labor installation costs would demonstrate affordability and better use of rate-payer monies.
- **Adoption of EPIC Technology**
  - A limited set of submeters has been developed and demonstrated at PG&E facilities as part of this EPIC project. Broader piloting may be conducted within PG&E's service territory as follow up to the EPIC project. If successful, additional funding in support of broader scale deployment may be requested through the GRC.
- **Support of CPUC Proceedings or State Requirements**
  - R.14-08-013 Distribution Resources Plan
  - R.09-08-009 Alternative-Fueled Vehicle
  - R.13-11-007 Alternative-Fueled Vehicles Programs
  - R.18-12-006 Vehicle Electrification Rates and Infrastructure
  - CPUC Draft Transportation Electrification Framework
- **Informed Industry and/or Company Standards**
  - The design changes made to the EV charge stations by integrating the NGM will be reflected in EV submetering standards.

Project 3.32 - System Harmonics for Power Quality Investigation

This project is demonstrating the use of modern SmartMeters to detect, investigate and mitigate harmonic issues on the distribution system. Harmonics issues on the grid negatively impact customer equipment operation and can also damage utility assets.

Benefits

- **Reliability**
  - The current process for identifying and responding to harmonics issues is reactive and manual. Having real time access to harmonics data will help shorten the investigation time and resolution of customer power quality issue which results in reduction of customer equipment downtime.
- **Economic Benefits**
  - Harmonics data from next generation metering technology will reduce labor hours and operational costs associated with power quality investigation due to harmonics issues. Successfully resolving harmonics issues for customers will also prevent customer loss of potential revenue due to equipment downtime.
- **Adoption of EPIC Technology**
  - Through the EPIC project, modern SmartMeters capable of capturing harmonics data have been deployed to a limited number of sites in areas with high harmonics issues, to support the completion of the demonstration. Early results have been very encouraging, and if the demonstration is successful, broader deployment across PG&E's service territory will be conducted using GRC funds.
- **Technology Development Progress**
  - Currently, not all AMI meters have harmonics capability. If the project is proven successful, more meter vendors may consider adding harmonics capability to their product offerings to utilities.
- **Support of CPUC Proceedings or State Requirements**
  - R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans

- **Informed Industry and/or Company Standards**
  - The project relies on the industry standard for harmonics (IEEE 519). The results of 3.32 which is using harmonics data from AMI meters may be shared with the IEEE 519 working group at the IEEE annual conference and other power quality organizations such as CEATI.

Project 3.41 - Drone Enablement

This project is demonstrating the feasibility and value of advanced drone operations for two important PG&E use cases. The first use case is exploring automated and Beyond Visual Line-of-Sight (BVLOS) drone operations to collect imagery needed for the routine inspection of complex, high-voltage transmission structures. The second use case is exploring automated and BVLOS dispatch of drones from PG&E substations to investigate alerts generated by distribution system sensors, such as those being demonstrated by PG&E's EPIC 2.34.

Benefits

- **Safety**
  - PG&E currently flies drones manually within visual Line-of-Sight (LOS) to capture the extensive sets of images used to inspect these structures. Automating drone flights and extending BVLOS has the potential to offer a highly safe, repeatable, and efficient process that will significantly improve upon the manual approach employed today. As sensor-based alerting systems are deployed more broadly within High Fire Threat Districts (HFTD), dispatching drones as the first line of investigation for potential asset issues could provide a safer solution compared to the current approach of sending crews in trucks to investigate every qualified event.
- **Reliability**
  - The automated dispatch of drones to investigate analytically-triggered alerts of potential asset issues could enable faster and improved verification of potential issues, and improved resolution of issues before assets fail and outages occur.

- **Economic Benefits**
  - Automating drone operations, extending drone operations beyond visual LOS, and sending drones to conduct preliminary investigations instead of crews in trucks or helicopters has the potential to result in significant reductions in operating costs. Imagery captured by drones will contribute to a robust foundation of data, enabling continued advancements in machine learning applications such as automated image classification, which will reduce the need for manual image review.
- **Adoption of EPIC Technology**
  - Each of the project's two use cases are being conducted at a limited geographic scale within PG&E's service territory. If successful, broader deployment to the transmission lines, substations and distribution circuits within PG&E's High Fire Threat Districts will be requested through the GRC.
- **Technology Development Progress**
  - This project is already informing significant enhancements to two drone vendor solution offerings, to better support utility needs. If successful, the project will also inform additional viable pathways for securing FAA approval for BVLOS operations in support of PG&E use cases that will also be applicable to other utilities.
- **Support of CPUC Proceedings or State Requirements**
  - R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans
- **Informed Industry and/or Company Standards**
  - This project has involved coordination with the FAA on the development and hopefully future approval of a Part 107 waiver application, to enable drone operations for PG&E's two use cases. This could help pave the way for other utilities subsequently requesting FAA approval for similar use cases.

Project 3.43 - Predictive Maintenance Leveraging SmartMeter Blinks

This project is leveraging multiple sources of data, including but not limited to SmartMeter, time of day, location, and weather data, to proactively identify potential problems in the Electric Distribution system, specifically related to identifying locations with high incidences of momentary outages which may be caused by imminent failures of conductors, insulators, transformers and/or vegetation contact.

Benefits

- **Safety**
  - Prediction of equipment requiring maintenance may potentially reduce public and employee exposure to hazardous catastrophic equipment failure.
- **Reliability**
  - Predictive equipment maintenance may potentially reduce unscheduled outages caused by failed equipment.
- **Economic Benefit**
  - Predicting that line equipment will require maintenance means that maintenance can be scheduled within normal operating workflow and avoid expensive unscheduled maintenance. Permitting targeted inspections as opposed to periodic inspections will better optimize field resources. Improved equipment operation will help optimize system performance
- **Support of CPUC Proceedings or State Requirements**
  - R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans
- **Adoption of EPIC Technology**
  - Upon successful demonstration the capabilities developed in this project will be transitioned to production and may require additional enhancements and broader scale rollout using GRC funds. The insights from this project may also help to inform broader GRC requests.

Project 3.44 - Advanced Transformer Protection

This project will demonstrate and evaluate a novel protective relay for large substation transformers using negative-sequence transformer differential protection. This novel protection method would provide high sensitivity fault detection to detect internal winding faults. When left undetected over long periods of time, low-magnitude turn-to-turn faults can develop into a more severe fault that can cause a catastrophic transformer failure. This failure can result in a hazardous Boiling Liquid Expanding Vapor Explosion (BLEVE) and would also take a large and expensive asset out of service unexpectedly.

Benefits

- **Safety**
  - The novel protective relay would eliminate catastrophic failures of substation transformer due to low-magnitude internal turn-to-turn faults.
  - This project would prevent catastrophic transformer failures like Boiling Liquid Expanding Vapor Explosions (BLEVE) from occurring.
- **Reliability**
  - Advanced transformer protection will reduce the number of unplanned outages associated with internal turn-to-turn faults.
- **Economic Benefits**
  - This project would closely monitor the health of substation transformers while in operation. If accelerated transformer failure was detected, this could be repaired before it gets worse and causes failure before the transformer's useful life.
- **Support of CPUC Proceedings or State Requirements**
  - PUC § 8360-8369: CA Grid Modernization Policy[64]

64. https://california.public.law/codes/ca_pub_util_code_div_4.1_chap_4.

Project 3.45 - Automated Fire Detection from Wildfire Alert Cameras

Existing California wildfire camera infrastructure is a passive and human operated system where cameras are manually operated and used to confirm satellite heat detections or IRWIN alerts.[65] It is important to identify the location of an ignition in the initial stage of a wildfire to suppress it while the scale is manageable. The goal of EPIC 3.45 is demonstrate that machine learning and enhanced camera/computer vision technologies can provide an alternative to existing wildfire ignition detection methods with a reduced ignition to detection time with low false positive and false negative rates. These novel techniques will be integrated into the Hazard Awareness and Warning Center (HAWC) capabilities and workflow and has a viewshed goal of 90 percent of High Fire Threat District (HFTD) Tier 2 and Tier 3. The project will also evaluate enhanced features such as nighttime detection and triangulation accuracy.

Benefits

- **Safety**
    - This project would enable faster detection of fires and this would allow for faster notification of first responders to move resources to the right place to suppress the fire. As a result, this would help reduce the frequency and/or severity of catastrophic fires.
- **Economic Benefits**
    - PG&E will have access to 600 cameras by end of 2022 from 486 in 2021. Rather than manually monitoring these cameras, this project could result in no additional staff for extra manual camera observations. The faster ignition to detection time enabled by this project would reduce the severity of wildfires and reduce the damage to property.
- **Environmental Benefits**
    - This project would result in a reduction in fire severity which would reduce GHG emissions and particulate matter from wildfire smoke.

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65. https://www.alertwildfire.org/.

- **Support of CPUC Proceedings or State Requirements**
    - R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans

Project 3.46 - Advanced Electric Inspection Tools for Wood Poles

This project seeks to develop a new, non-destructive testing method to analyze the condition of wood poles to provide a more complete analysis of the overall health and condition of existing wood poles. The proposed non-destructive method is radiographic testing (RT) which is where radiation is passed through an object and the material density and thickness absorbs the radiation and reveals the internal composition without the need for intrusive testing.

Benefits

- **Reliability**
    - PG&E identifies approximately 10,000 wood poles for replacement and 4,000 wood poles for reinforcement every year. This project would provide quality data that depicts wood pole health and condition. This better data may either help identify more wood poles that should be replaced or repaired, or it may support a reduction in wood pole replacements due the higher quality data on pole health and condition.
- **Economic Benefits**
    - This better data may either help identify wood poles that should be replaced or repaired, or it may support a reduction in wood pole replacements due the higher quality data on pole health and condition.

Project 3.47 - Operational Vegetation Management Efficiency Through Novel Onsite Equipment

This project's objectives are to complete one or more technology demonstrations which could improve upon such wood handling metrics when deployed at scale. Two technologies that will be solicited in the RFP are wood baling and mobile torrefaction. Baling is expected to reduce labor requirements and processing costs. Mobile torrefaction is a process to create valuable products from heat treating woody biomass and could eliminate 'tipping fees' while having an added benefit of reducing the carbon intensity of our energy portfolio.

Benefits

- **Safety**
    - Vegetation management is a huge undertaking at PG&E and has many hazards. This project would result in fewer truck loads and vehicle trips and would reduce the number of hours workers spend in vehicles.
    - There is increased safety due to less frequent use of dangerous chippers.
- **Economic Benefits**
    - The forecasted cost of enhanced vegetation and wood management is about $40M per year. Wood disposal costs vary year to year but could be expected to be roughly $100M per year. The fraction of PG&E wood management costs displaced will depend on the success of the technology demonstrations of this project. Assuming even a small improvement in efficiency would result in millions of dollars of savings per year.
- **Environmental Benefits**
    - The project would result in lower GHG emissions and air pollution through a reduction of vehicle travel with fewer vegetation management crews.
    - Some proposed technologies also propose carboned sequestration which would reduce GHG emissions.
- **Support of CPUC Proceedings or State Requirements**

- R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans

APPENDIX D: Alignment of PG&E's EPIC 4 Investment Plan with DER Action Plan Version 2.0

PG&E's EPIC 4 Investment Plan filed on October 3, 2022 includes a number of topics that are aligned with, and supportive of, the goals and actions detailed in the Commission's DER Action Plan Version 2.0. Research Topics within PG&E's EPIC 4 Investment Plan would apply to the following Tracks, Vision Elements, and Action Elements of the DER Action Plan Version 2.0:

DER Action Plan Track	Vision Element	Supported by PG&E EPIC 4 Investment Plan
Track 1 Load Flexibility and Rates	1A	11. Interconnection Enablement, 12. Advanced Distribution Power Flow Management
	1D	12. Advanced Distribution Power Flow Management
	1E - 1F	12. Advanced Distribution Power Flow Management
	1G	12. Advanced Distribution Power Flow Management
	1H	12. Advanced Distribution Power Flow Management, 13. Electric Vehicle Charging and Integration Enablement
Track 2 Load Flexibility and Rates	2A	12. Advanced Distribution Power Flow Management
	2C	1. Microgrid Enablement, 3. Long Duration Energy Storage, 4. Integration of New Generation Technologies, 11. Interconnection Enablement, 12. Advanced Distribution Power Flow Management, 13. Electric Vehicle Charging and Integration Enablement
	2D	1. Microgrid Enablement, 12. Advanced Distribution Power Flow Management, 13. Electric Vehicle Charging and Integration Enablement
	2E	6. Grid Scenario Planning, 11. Interconnection Enablement, 12. Advanced Distribution Power Flow Management
Track 3 Market Integration	3A-3C	3. Long Duration Energy Storage, 12. Advanced Distribution Power Flow Management, 13. Electric Vehicle Charging and Integration Enablement
Track 4 DER Customer Programs	4F	14. Electric Vehicle Battery Re-Use for Stationary Energy Storage

Track 1: Load Flexibility and Rates

Vision Element 1A: Available dynamic and real time pricing rate options that address load flexibility

This vision element is supported by PG&E's EPIC 4 Investment Plan Topic 11, "Interconnection Enablement", and Topic 12, "Advanced Distribution Power Flow Management", as these topics will yield projects that develop and demonstrate technologies that enable load flexibility and compensation models. Such demonstrations and increased visibility into distribution systems could inform the vision element goal of understanding customer preference for dynamic rates and generation rate components.

Vision Element 1D: Available rates reflect cost causation and provide opportunities for fair compensation

Topic 12, "Advanced Distribution Power Flow Management", supports this vision element's Action Element 3 through the demonstration of compensation mechanisms for DER owners that participate in grid support activities that would inform a proposal for opt-in and opt-out rates for this customer segment. Demonstrations of local DER orchestration will be needed to evaluate available technologies, determine regulatory pathways, and determine fair compensation options.

Vision Elements 1E-1F: Time-varying rate options are available to load management technologies through pricing platform and communicated to all customer segments

Topic 12, "Advanced Distribution Power Flow Management", indirectly supports this Vision Element through informing of some of the costs that would feed into rate design as well as the pricing platform, and subscription services.

Vision Element 1H: Electric Vehicle-related assets owners and managers respond to price or load management signals that reflect real-time and dynamic costs and benefits of charging

Topic 12, "Advanced Distribution Power Flow Management", and Topic 13, "Electric Vehicle Charging and Integration Enablement", support this Vision Element through the demonstration of flexible load management and compensation mechanisms for BTM energy storage and EV owners that participate in optimized managed EV charging load, as well as energy export services (vehicle-to-grid exports).

Track 2: Grid Infrastructure

Vision Element 2A: CPUC to guide utilities to modernize the electric grid for a high DER future

Topic 12, “Advanced Distribution Power Flow Management”, supports Vision Element 2A with the development and demonstration of an automated operational tool that would coordinate and optimize dispatching of all available FTM DERs as well as BTM DERs including EVs and flexible loads. Additionally, the tool would provide hourly and day ahead distribution forecasts for a feeder. This topic would also inform PG&E on how such a tool would progress toward operationalization in a Distribution System Operator (DSO) model. Such a tool would enable localized DER orchestration and support the vision for a high DER grid in line with State policy objectives.

Vision Element 2C: Continuously improve interconnection performance, leading to greater transparency, cybersecurity, speed, and cost certainty

This vision element’s Action Element 1 is supported by Topic 11, “Interconnection Enablement”, through reducing or eliminating the time it takes to complete the interconnection for DERs thereby supporting DER adoption in line with California’s clean energy goals. The aim of Topic 11 is to speed or eliminate interconnection queue time through exploring and preparing to operationalize a wide range of solutions for eliminating barriers to timely, smarter, more flexible customer service connection and generation interconnection. This would be done through making more efficient use of limited available distribution service capacity and avoiding significant grid infrastructure upgrades that would bring long lead times and investment challenges.

This vision element’s Action Element 2 is supported by Topic 1, “Microgrid Enablement”, as an aim of this topic is to develop standardized microgrid designs and validated equipment and configuration lists that can help reduce the cost of DER integration or optimize the benefits of the DERs within microgrids. This Action Element 2 is also supported by Topic 2, “Individual Customer Resiliency”, with its backup power transfer meters and other related grid equipment, that would inform the envisioned transparent technical review process.

This vision element’s Action Element 3 is supported by Topic 12, “Advanced Distribution Power Flow Management”, and its expansion of the use of the IEEE 2030.5 communications protocol for telemetry and its use of advanced smart inverter control functions for operational flexibility.

This vision element’s Action Element 4 is supported by Topic 13, “Electric Vehicle Charging and Integration Enablement”, with its intent to establish methods to automatically detect and track the installation of V2G interconnections, then informing the ADMS/DERMS in coordinating BTM DERs.

This vision element’s Action Element 6 is supported by Topic 3, “Long Duration Energy Storage”, Topic 1, “Microgrid Enablement”, and Topic 4, “Integration of New Generation Technologies”, as each of these topics include hydrogen-based fuel creation, generation, and storage demonstrations. The projects within these three topics would establish methods for tracking energy stored in the form of hydrogen and subsequently returned to the grid, including tracking the method of production for that stored hydrogen.

Vision Element 2D: Implement new standards to facilitate visibility, operational control, provision of grid services, and interoperability of DERs, while maintaining cybersecurity

This vision element’s Action Elements 1-4 are supported by Topic 1, “Microgrid Enablement”, Topic 12, “Advanced Distribution Power Flow Management”, and Topic 13, “Electric Vehicle Charging and Integration Enablement”, as these three topics will yield projects that advance smart inverter operationalization use case demonstration, interoperability of DERs, as well as identify, enhance or establish standards and best practices needed to facilitate the interoperability of DERs on the evolving distribution grid.

Vision Element 2E: Integrate impacts of electrification into distribution planning to maximize public benefits, minimize costs, and optimize deployment of complimentary and supporting infrastructure

This vision element's Action Element 1 is supported by Topic 6, "Grid Scenario Planning," Topic 11, "Interconnection Enablement", and Topic 12, "Advanced Distribution Power Flow Management", as projects within these topics would aim to demonstrate the optimization of distribution grid investments in a high DER scenario, including through automated load management and flexible interconnection, and thus could inform the envisioned study.

Track 3: Market Integration

Vision Elements 3A-3C: Enable Energy storage and hybrid configurations with other DERs to participate in wholesale markets, determine fair compensation, rules, and procedures for DER participation

These vision elements are supported by a combination of Topic 3, "Long Duration Energy Storage", and Topic 12, "Advanced Distribution Power Flow Management", along with Topic 13, "Electric Vehicle Charging and Integration Enablement", as these topics can inform methods to efficiently integrate all types of energy storage technologies and to create compensation mechanisms that support the State's goals. In addition, projects within Topic 23, "Granular Attributes for Environmental Commodity Tracking", would support the additional participation of DERs in markets through the demonstration of an additional price signal for renewable generation.

Track 4. DER Customer Programs

Vision Element 4C-D: Understanding the impact of DER programs on middle-income ratepayers and ESJ and tribal communities is an inherent part of program design and management

These vision elements are supported by PG&E's commitment to equity as an underlining principle of EPIC planning, project design, demonstration, and stakeholder engagement throughout the project, as described in "Chater 1: Introduction and Background" of the EPIC 4 Investment Plan.

Vision Element 4F: End-of-life management programs are in place to ensure the effective collection, safe transport, and environmentally responsible recycling or re-use of DERs

Action Element 2 is supported by Topic 14, “Electric Vehicle Battery Re-Use for Stationary Energy Storage”, as this topic targets second life for electric vehicle batteries in energy storage systems and could therefore inform recommendations and programs that ensure the effective and environmentally responsible re-use or recycling of batteries at their end of life.

APPENDIX E: Alignment of PG&E's EPIC 4 Investment Plan with CPUC Environmental and Social Justice Action Plan

PG&E continues to support including equity as a guiding EPIC principle. In this EPIC 4 Investment Plan, we have proposed a set of 23 Research Topics that is expected to provide a wide range of equity benefits, including health and safety benefits and financial benefits. These Research Topics align with and advance the CPUC's Environmental and Social Justice Action Plan Goals. Listed below in the table are the CPUC ESJ Action Plan Goals applicable to PG&E.

Applicable CPUC ESJ Action Plan Goal	Supported by PG&E EPIC 4 Investment Plan
1. Consistently integrate equity and access considerations throughout CPUC regulatory activities	See written section below.
2. Increase investment in clean energy resources to benefit ESJ communities	Topic 1. Microgrid Enablement
	Topic 2. Individual Customer Resilience
	Topic 13. Electric Vehicle Charging and Integration Enablement
3. Strive to improve access to high-quality water, communications, and transportation services for ESJ communities.	Topic 13. Electric Vehicle Charging and Integration Enablement
4. Increase climate resiliency in ESJ communities	Topic 1. Microgrid Enablement
	Topic 2. Individual Customer Resilience
	Topic 3. Long Duration Energy Storage
	Topic 13. Electric Vehicle Charging and Integration Enablement
	Topic 16. Undergrounding Capabilities
5. Enhance outreach and public participation opportunities for ESJ communities to meaningfully participate in the CPUC's decision-making process and benefit from CPUC programs	See written section below.
7. Promote high road career paths and economic opportunity for residents of ESJ communities	Topic 21. Climate and Nature-Positive Operations
9. Monitor the CPUC's ESJ efforts to evaluate how they are achieving their objectives	See written section below.

Goal 1. Consistently integrate equity and access considerations throughout CPUC regulatory activities

PG&E integrates equity and access considerations into both the development process (procedural equity) and implementation (distributional equity) of the EPIC 4 Investment Plan.

As part of the development of the EPIC 4 Investment Plan, PG&E hosted two workshops for the general public, two workshops for DAC representative groups, as well as numerous consultation meetings with the CPUC and CEC. These workshops, as a whole, were well-attended with a broad spectrum of participants, including academia, industry, and research institutions, as well as environmental, customer advocates and community-based organizations. Additionally, PG&E has collaborated with the PG&E Community Perspectives Advisory Committee (CPAC) to incorporate broader community feedback and identify opportunities to partner with communities to host projects that will have field demonstration components.

Implementing the EPIC 4 Investment Plan will include dedicating at least 25 percent of technology demonstration and deployment (TD&D) funds toward projects located in and benefitting disadvantaged communities and at least an additional 10 percent allocation of TD&D funds toward projects located in and benefitting low-income communities.

Goal 2. Increase investment in clean energy resources to benefit ESJ communities, especially to improve local air quality and public health

Topic 1, “Microgrid Enablement” will explore solutions to provide clean, back-up power for remote areas, providing emissions-free service, and in some instances also reducing wildfire risk. Disadvantaged and low-income communities, especially in the wildland urban interface and high fire threat districts, will be engaged to help with demonstrations and resulting benefits from it in those communities.

Topic 2, “Individual Customer Resilience,” will demonstrate technologies to provide customer greater resiliency at lower costs for individual residential and non-residential customers impacted by Public Safety Power Shutoffs (PSPS) and Enhanced Powerline Safety Settings (EPSS) events. DERs support individual customer resilience through clean, non-polluting energy, like electric vehicles and energy battery storage. This strategy can avoid the need for diesel generators, fires, and other polluting sources of energy or heat, contributing to improved local air quality and public health.

Topic 13, “Electric Vehicle Charging and Integration Enablement Research Topic,” seeks to accelerate both the adoption and expanded access of electric vehicles, especially in ESJ communities. Disadvantaged and low-income communities will be targeted for demonstration to help with transportation electrification and attendant benefits from it in those communities. Since DACs might not have the high penetration of EVs that would be needed as the basis to conduct the demonstrations, PG&E will look for opportunities to align EPIC funds with resources from other customer programs and upcoming Federal funding opportunities to provide communities with the EVs needed as the basis for the demonstrations. When conducting demonstration projects, transportation electrification can reduce internal combustion engine emissions, and improve air quality in the communities where technology is demonstrated.

Goal 3. Strive to improve access to high-quality water, communications, and transportation services for ESJ communities.

Topic 13, “Electric Vehicle Charging and Integration Enablement,” seeks to accelerate both the adoption and expanded access of electric vehicles, especially in ESJ communities. Disadvantaged and low-income communities will be targeted for demonstration to help with transportation electrification and attendant benefits from it in those communities.

Goal 4. Increase climate resiliency in ESJ communities

Given the increasing frequency of heat waves, intensity of drought, and intensity of storms from climate change, climate resilience continues to be a major focus of the EPIC Program.

Topic 1, "Microgrid Enablement" will explore solutions making electricity service for remote areas significantly more reliable, reducing or eliminating disruptions caused by extreme weather-related power outage events, providing emissions-free service, and in some instances also reducing wildfire risk. Disadvantaged and low-income communities, especially in the wildland urban interface and high fire threat districts, will be targeted for demonstration to help with demonstrations and resulting benefits from it in those communities.

Topic 2, "Individual Customer Resilience" will demonstrate technologies to provide customer greater resiliency at lower costs for individual residential and non-residential customers impacted by power shutoff events.

As unpredictable and extreme weather conditions continue to impact California as a result of climate change, Topic 3, "Long Duration Energy Storage," can play a critical role in ensuring electric reliability across long periods of low renewable generation and even across seasons. By demonstrating technologies in disadvantaged and low-income communities, these customers can see the local benefits of increased electric reliability.

Topic 13, "Electric Vehicle Charging and Integration Enablement" will explore how customers could use vehicle-to-anything (V2X) integration for customer resiliency for planned and unplanned grid outages, in support of the electric grid, or for other potentially beneficial use cases. Disadvantaged communities and low-income will be targeted for demonstration to help with V2X enablement and resulting benefits from it in those communities.

Topic 16, "Undergrounding Capabilities," will demonstrate emerging technologies that have the potential to increase the speed, efficiency, and predictability of undergrounding, as well as potentially extend the life of assets with intelligent monitoring. Improvements in these areas would lead to faster reduction of wildfire risk in these areas and maintaining longer asset life, without jeopardizing safety and reliability. Vulnerable communities in high fire risk areas could have service undergrounded sooner than otherwise would be possible, reducing their exposure to wildfire risk and reducing wildfire-related public health impacts.

Goal 5. Enhance outreach and public participation opportunities for ESJ communities to meaningfully participate in the CPUC's decision-making process and benefit from CPUC programs

By requiring that all EPIC Administrators dedicate at least 25 percent of technology demonstration and deployment (TD&D) funds toward projects located in and benefiting disadvantaged communities and at least an additional 10 percent allocation of TD&D funds toward projects located in and benefitting low-income communities, the EPIC Program directly benefits ESJ Communities and engenders opportunity for public participation.

Goal 7. Promote high road career paths and economic opportunity for residents of ESJ communities

Topic 21, "Climate and Nature-Positive Operations," will assess technology options and conduct demonstrations of climate and nature-positive solutions. For instance, PG&E seeks to improve operational efficiency, environmental performance, and worker safety across the woody biomass value chain from locational targeting to collection, in situ processing, removal, and development of value-added carbon re-use products. Under-resourced rural and ESJ communities could benefit both from improved public safety and potential new economic opportunity associated with climate and environment-positive value chains.

Goal 9. Monitor the CPUC's ESJ efforts to evaluate how they are achieving their objectives

In each Research Topic section, PG&E identifies potential metrics and performance indicators to track in future projects. In addition to tracking the budget related to TD&D work, PG&E will seek to capture qualitative and quantitative benefits of demonstrations in disadvantaged and low-income communities. Metrics will be shared in the EPIC Annual Report, as well as, in each project's final report.

APPENDIX F: Alignment of PG&E's EPIC 4 Investment Plan with Department of Energy Justice40 Initiative

In 2021, the Biden Administration institutionalized the federal government's commitment to environmental justice through the Executive Order 14008 and it's Justice40 Initiative. Justice40 aims to ensure "that 40 percent of the overall benefits of certain Federal investments flow to disadvantaged communities that are marginalized, underserved, and overburdened by pollution."[66] Investment categories include: climate change, clean energy and energy efficiency, clean transit, affordable and sustainable housing, training and workforce development, remediation and reduction of legacy pollution, and the development of critical clean water and wastewater infrastructure.[67] Listed below in the table are the Justice40 Investment Categories applicable to PG&E.

Applicable Justice40 Investment Category	Supported by PG&E EPIC 4 Investment Plan
Climate Change	Topic 1. Microgrid Enablement
	Topic 2. Individual Customer Resilience
	Topic 3. Long Duration Energy Storage
	Topic 13. Electric Vehicle Charging and Integration Enablement
	Topic 16. Undergrounding Capabilities
Clean Energy and Energy Efficiency	Topic 1. Microgrid Enablement
	Topic 2. Individual Customer Resilience Research Topic
	Topic 11. Interconnection Enablement
	Topic 13. Electric Vehicle Charging and Integration Enablement
Clean Transit	Topic 13. Electric Vehicle Charging and Integration Enablement
	Topic 14. Electric Vehicle Battery Re-Use for Stationary Energy
Training and Workforce Development	Topic 21. Climate and Nature-Positive Operations

66 https://www.whitehouse.gov/environmentaljustice/justice40/

67 Interim Implementation Guidance for the Justice40 Initiative, https://www.whitehouse.gov/wp-content/uploads/2021/07/M-21-28.pdf, (2021)

Climate Change

Given the increasing frequency of heat waves, intensity of drought, and intensity of storms from climate change, climate resilience continues to be a major focus of the EPIC Program.

Topic 1, "Microgrid Enablement" will explore solutions making electricity service for remote areas significantly more reliable, reducing or eliminating disruptions caused by extreme weather-related power outage events, providing emissions-free service, and in some instances also reducing wildfire risk. Disadvantaged and low-income communities, especially in the wildland urban interface and high fire threat districts, will be targeted for demonstration to help with demonstrations and resulting benefits from it in those communities.

Topic 2, "Individual Customer Resilience" will demonstrate technologies to provide customer greater resiliency at lower costs for individual residential and non-residential customers impacted by power shutoff events.

As unpredictable and extreme weather conditions continue to impact California as a result of climate change, Topic 3, "Long Duration Energy Storage," can play a critical role in ensuring electric reliability across long periods of low renewable generation and even across seasons. By demonstrating technologies in disadvantaged and low-income communities, these customers can benefit from increased local electric reliability.

Topic 13, "Electric Vehicle Charging and Integration Enablement" will explore how customers could use vehicle-to-anything (V2X) integration for customer resiliency for planned and unplanned grid outages, in support of the electric grid, or for other potentially beneficial use cases. Disadvantaged and low-income communities will be targeted for demonstration to help with V2X demonstrations and resulting benefits from it in those communities.

Topic 16, "Undergrounding Capabilities," will demonstrate emerging technologies that have the potential to increase the speed, efficiency, and predictability of undergrounding, as well as potentially extend the life of assets with intelligent monitoring. Improvements in these areas would lead to lower costs for customers, quicker reduction of wildfire risk in these areas, and maintaining longer asset life, without jeopardizing safety and reliability. Vulnerable communities in high fire risk areas could have service undergrounded sooner than otherwise would be possible, reducing their exposure to wildfire risk and reducing wildfire-related public health impacts.

Clean Energy and Energy Efficiency

Topic 1, “Microgrid Enablement” will explore solutions to provide clean, back-up power for remote areas, providing emissions-free service, and in some instances also reducing wildfire risk. Disadvantaged and low-income communities, especially in the wildland urban interface and high fire threat districts, will be engaged to help with demonstrations and resulting benefits from it in those communities.

Topic 2, “Individual Customer Resilience,” will demonstrate technologies to provide customer greater resiliency at lower costs for individual residential and non-residential customers impacted by Public Safety Power Shutoffs (PSPS) and Enhanced Powerline Safety Settings (EPSS) events. DERs support individual customer resilience by providing clean, non-polluting electricity, through electric vehicles and energy battery storage. This strategy can avoid the need for diesel generators, fires, and other polluting sources of energy or heat, contributing to improved local air quality and public health.

Topic 11, “Interconnection Enablement,” will demonstrate a range of solutions for enabling the interconnection of distributed energy resources and new service connections of new and growing residential and commercial customers’ loads and DERs, beyond conventional upgrades to conductors and transformers or the establishment of static constraints as a prerequisite for interconnection. Accelerating interconnection enablement is a critical step in removing barriers for disadvantaged and low-income customers to access clean DERs within their communities.

Topic 13, “Electric Vehicle Charging and Integration Enablement Research Topic,” seeks to accelerate both the adoption and expanded access of electric vehicles, especially in ESJ communities. Disadvantaged and low-income communities will be targeted for demonstration to help with transportation electrification and attendant benefits from it in those communities.

When conducting demonstrations, transportation electrification can reduce internal combustion engine emissions, improves air quality in the DACs where technology is demonstrated.

Clean Transit

Topic 13, "Electric Vehicle Charging and Integration Enablement," seeks to accelerate both the adoption and expanded access of electric vehicles, especially in ESJ communities. Disadvantaged and low-income communities will be targeted for demonstration to help with transportation electrification and attendant benefits from it in those communities.

Topic 14, "Electric Vehicle Battery Re-Use for Stationary Energy," intends to conduct demonstration and analysis to identify key utility requirements for the efficient and effective deployment of second-life batteries as grid scale resources. In addition to extending the life span of electric vehicle batteries, PG&E customers could also benefit from lower energy bills as grid-connected energy storage built with second-life batteries may be less expensive than that built with new batteries.

Training and Workforce Development

Topic 21, "Climate and Nature-Positive Operations," will assess technology options and conduct demonstrations of climate and nature-positive solutions. For instance, PG&E seeks to improve operational efficiency, environmental performance, and worker safety across the woody biomass value chain from locational targeting to collection, in situ processing, removal, and development of value-added carbon re-use products. Under-resourced rural and ESJ communities could benefit both from improved public safety and potential new economic opportunity associated with climate and environment-positive value chains.

ATTACHMENT 2
Updated Pacific Gas and Electric Company
2021– 2025 Electric Program Investment Charge
Investment Plan (Redline)

Pacific Gas and Electric Company

Electric Program Investment Charge (EPIC)

~~Proposed~~ Updated EPIC 4 2021-2025 Investment Plan

~~October 3~~January 16~~2~~, 202~~2~~4

ACKNOWLEDGMENT

PG&E's ~~proposed~~ Updated EPIC 4 2021-2025 Investment Plan was prepared by ~~Dan Gilani, Damian Inglin, Ian Burnside, and Dave O'Connor of~~ PG&E's Engineering, Planning, and Strategy group.

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EXECUTIVE SUMMARY

The California Public Utilities Commission (Commission) established the Electric Program Investment Charge (EPIC) in 2011 and renewed the Program in 2020. The Commission's mission for EPIC is to "invest in innovation to ensure equitable access to safe, affordable, reliable, and environmentally sustainable energy for electricity ratepayers." The original EPIC guiding principles were to provide benefits to customers with a focus on safety, reliability, and affordability.

On November 22, 2021, the Commission issued Decision (D.) 21-11-028, authorizing Pacific Gas and Electric Company (PG&E), Southern California Edison Company (SCE), and San Diego Gas & Electric Company (SDG&E), collectively the investor-owned utilities (IOUs) or Utilities, to continue in their role as EPIC program administrators, along with the California Energy Commission (CEC). The Commission further determined that the CEC would continue to receive 80 percent of the budget with the IOUs sharing the remaining 20 percent.

In D.21-11-028, the Commission instructed PG&E, along with SCE and SDG&E, to each file an EPIC Investment Plan Application covering 2021-2025 on October 1, 2022. This period is known as EPIC 4. PG&E's authorized budget for EPIC 4 is $92,685,000, inclusive of PG&E's project and administrative budgets, as well as Commission oversight cost.

PG&E's past and ongoing EPIC projects have provided significant value to its utility customers by facilitating and accelerating the integration of new technologies into the electric grid and into utility operations, and helping to advance the safety, affordability, reliability, and delivery of clean energy to customers. EPIC projects are critical toward helping California achieve its energy and environmental policy goals and support key Commission proceedings.

PG&E's EPIC 4 Investment Plan proposes topics that will continue to drive innovation to support California's progress toward an equitable clean energy future. PG&E's EPIC 4 Investment Plan focuses on advancements toward carbon-neutrality, expanding the potential benefits of distributed energy resources and creating a more resilient grid to impacts from climate change and other emerging threats.

During the development of the IOUs' respective EPIC 4 Investment Plans, extensive stakeholder engagement was conducted. The IOUs jointly held four public workshops, including two public workshops targeted to disadvantaged and vulnerable communities. Additionally, the IOUs provided a joint presentation to the Disadvantaged Communities Advisory Group (DACAG). The IOUs also jointly held numerous discussions to ensure their respective plans avoid unnecessary duplication, while complimenting the CEC's EPIC 4 Plan and the Commission's proceedings. PG&E has incorporated feedback from the DACAG to better embed equity by applying the principles of the DACAG's equity framework to PG&E's EPIC 4 Plan. PG&E has included an equity matrix with our proposed topics and their anticipated direct and indirect equity impacts.

PG&E's EPIC 4 Investment Plan is composed of three areas of strategic investment, called Strategic Objectives. PG&E, SCE, and SDG&E were directed by the Commission to use, as applicable, the Strategic Objectives and Initiatives that are in the CEC's EPIC 4 Investment Plan, as a framework for developing and presenting their own underlying distinct investment topics in their investment plans. Within these three Strategic Objectives, PG&E has proposed to pursue five Initiatives, which are specific opportunities or challenges. Details of how these opportunities or challenges will be operationalized are provided in 23 underlying topics. These Strategic Objectives, Initiatives and Topics are described herein.

Strategic Objective: Create a More Nimble Grid to Maintain Reliability as California Transitions to 100 Percent Clean Energy

PG&E's electric system will undergo substantial changes as it transitions away from reliance on the remaining large fossil-fueled power plants and moves toward a grid dominated by intermittent renewable and distributed generation as well as energy storage systems to deliver 100 percent renewable and zero-carbon electricity. The grid will need to become more flexible, with different resources, and with greater control over when, where, and how much energy flows. EPIC Research, Development and Demonstration (RD&D) will play an important role, both by developing technologies to help maintain electric reliability and resilience and creating modeling and decision tools to identify tradeoffs and optimal deployment strategies for the coming decades. PG&E's topics in this strategic objective are grouped into two initiatives: the Clean, Dispatchable Resources initiative; and the Grid Modernization initiative. The topics within these initiatives will help develop the technologies and modeling capabilities that enable a more flexible electric grid, one that is able to meet our customers' needs, and is reliable, cybersecure, and decarbonized. PG&E is collaborating with the CEC and the other Utility EPIC Administrators as they share this same strategic objective. For certain of the CEC's and PG&E's topics, in particular, PG&E intends to closely collaborate with the CEC on joint projects, working together per our respective roles on the support, development, interconnection, operation, and analysis that will be important for delivering the full benefits of the related research and demonstration.

Strategic Objective: Increase the Value Proposition of Distributed Energy Resources to Customers and the Grid

Distributed energy resources (DERs) are key to achieving California's clean energy goals. DERs have the potential to deliver significant benefits to grid operators and electricity users in a high-renewable, highly electrified future. These potential benefits include load flexibility, peak demand reductions, reducing or deferring grid upgrades and associated costs, improving climate resiliency, grid reliability, and providing compensation to DER owners. There are, however, operational challenges to integrating and maximizing the value of DERs on the grid. The topics in this strategic objective are grouped into the Distributed Energy Resources and Load Flexibility initiative, and the Transportation Electrification initiative. The topics will help develop the technologies and operational capabilities that will improve our understanding of how to maximize the value of DERs to customers and the grid.

Strategic Objective: Inform California's Transition to an Equitable, Zero-Carbon Energy System that is Climate-Resilient and Meets Environmental Goals

As California transitions to an equitable, zero-carbon energy system, PG&E must ensure that the grid is resilient and reliable in the face of climate change, and support California's and its own environmental goals. The EPIC program can be instrumental to providing the sustained investment needed for technology development and demonstration to address the significant challenges ahead to arrive at this future. PG&E's nine topics in this strategic objective are wide-ranging and include new modeling, new and emerging equipment, new inspection and analysis methods, new operational processes, and new ways of interacting with customers. All of these topics are grouped into the single Climate and Environment initiative.

CHAPTER 1: Introduction and Background

Regulatory Background

The California Public Utilities Commission (Commission) established the Electric Program Investment Charge (EPIC) in 2011[1] and renewed the Program in 2020[2]. The Commission's mission for EPIC is to "invest in innovation to ensure equitable access to safe, affordable, reliable, and environmentally sustainable energy for electricity ratepayers."[3] The original EPIC guiding principles were to provide benefits to customers with a focus on safety, reliability, and affordability. On November 22, 2021, the Commission issued D.21-11-028 authorizing the IOUs to continue as EPIC program administrators, along with the California Energy Commission (CEC). The Commission further determined that the CEC would continue to receive 80 percent of the budget with the IOUs sharing the remaining 20 percent of the budget[4]. PG&E's authorized EPIC 4 budget is $92,685,000, inclusive of PG&E's project and administrative budgets, as well as Commission oversight cost. The Commission instructed PG&E, along with SCE and SDG&E to each file an EPIC 4 Investment Plan Application covering 2021-2025 on October 1, 2022[5]. The Commission further directed all Administrators to file EPIC 4 investments plans at the initiative level, and defined initiatives as the strategies EPIC Administrators employ to meet their high-level strategic objectives. EPIC Administrators were also directed to propose funding levels for their initiatives and specify how these initiatives will be operationalized, including the proposed activities[6].

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1. D.11-12-035.
2. D.20-08-042.
3. D.21-11-028, Appendix A.
4. D.21-11-028, Appendix B.
5. D.21-11-028, OP 7.
6. D.21-11-028, OP 8.

This Decision also revised EPIC's Guiding Principles definition of ratepayer benefits to include improving safety, increasing reliability, increasing affordability, improving environmental sustainability, and improving equity. These benefits must accrue to customers and relate to the electric grid.[7] Benefits are discussed within each of the topics in PG&E's EPIC 4 Investment Plan.

Impact of PG&E's EPIC Program

PG&E's EPIC program has provided significant value to its customers through the evaluation, development, and demonstration of new or emerging technologies on the electric grid. PG&E's EPIC 1, 2 and 3 projects have provided customer benefits, which, prior to D.21-11-028, were defined as increased safety, improved reliability, reduced costs, and complementary benefits. These projects have provided additional value by supporting CPUC proceedings, influencing market products, informing industry standards, improving PG&E's GRC requests, and by providing a path to production for promising technologies.

In D.21-11-028, the Commission directed the IOUs to "coordinate with the California Energy Commission and this Commission's Energy Division staff to develop a single, uniform benefits analysis framework and set of metrics that enable the evaluation and tracking of the benefits of all EPIC projects."[8]. The Commission further directed the IOUs to "file a report documenting their success to date of the EPIC projects under its administration, using the metrics they are ordered to create in Ordering Paragraph 12, and in working with this Commission's Energy Division staff."[9] PG&E has coordinated extensively with SCE, SDG&E, the CEC and Commission Energy Division staff to create a common framework for benefits analysis of all EPIC projects. This framework was the basis for PG&E's EPIC 1, 2, & 3 Benefits Impact Report, which summarizes of qualitative and quantitative benefits for all of PG&E's completed EPIC 1 & 2

7. D.21-11-028, OP 2.
8. D.21-11-028, OP 12.
9. D.21-11-028, OP 13.

projects, as well as its active EPIC 3 projects. PG&E's EPIC 1, 2, & 3 Benefits Impact Report is included in this EPIC 4 Investment Plan Application as Appendix C.

Examples of PG&E's EPIC Program successes include the following:

- EPIC 1.01 - *Energy Storage End Uses* introduced the first utility-owned battery storage systems to help establish the California Independent System Operator's (CAISO) new Non-Generator Resource (NGR) market for battery participation and resolved multiple implementation issues with the NGR market model along the way. This served to enable the participation of future storage resources in the market, which now includes PG&E's own Elkhorn Energy Storage system. This project will enable $16 million per year in savings and reduce environmental emissions by 7,000 tonnes of CO_2 per year from PG&E Battery Energy Storage System (BESS) participation in the market.
- EPIC 1.05 - *Demonstrate New Resource Forecast Methods to Better Predict Variable Resource Output* deployed a new meteorological model that drastically improved the resolution of PG&E's weather modeling capabilities from 15km to 3km resolution and provided foundational improvement across a number of applications including winter storm and wildfire risk management. It is estimated that these capabilities enable the avoidance of 15.2 million customer minutes of interruption (CMI) per year and an associated $40.8 million per year in avoided customer economic impact.
- EPIC 1.14 - *Next Generation SmartMeter™ Telecom Network Functionalities*[10] developed the foundation for PG&E's SmartMeter Partial Voltage Detection system, which is now deployed across PG&E's service area. The faster detection of issues across PG&E's system enabled by this technology reduces 8 million CMI per year and provides an associated $22 million per year in avoided customer economic impact.
- EPIC 2.34 - *Predictive Risk Identification with Radio Frequency (RF) Added to Line Sensors* demonstrated Early Fault Detection (EFD) sensors that proved to be highly effective at identifying a wide range of developing asset issues early and pinpointing the geographic

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10. SmartMeter is a trademark of Pacific Gas and Electric Company.

locations of the issues with high precision. As a result of the successful demonstration, PG&E has begun working to deploy these sensors on 75 distribution feeders, which is expected to improve operating efficiency and reduce operating costs by $6 million per year.

- EPIC 3.03 - *Distributed Energy Resource Management System (DERMS) and Advanced Distribution Management System (ADMS) Advanced Functionality* developed and deployed a low-cost communication system to allow customers with large DERs to save around a total of $2.25 million per year in sending required telemetry data from their DERs back to PG&E.
- EPIC 3.11 - *Location-Specific Options for Reliability and/or Resilience Upgrades* pioneered multi-customer microgrid capabilities and operationalized the first multi-customer microgrid in PG&E's service area in collaboration with the CEC and numerous other parties. The foundational capabilities developed through this project directly defined the tariff structures and interconnection processes of PG&E's broader Community Microgrid Enablement Program (CMEP) and the Microgrid Incentive Program (MIP), which are now in the process funding the establishment of approximately a dozen microgrids. The associated reliability benefit attributed to this EPIC project is 160,000 CMI per year, corresponding to $3.9 million per year in customer economic benefit.
- EPIC 3.20 - *Data Analytics for Predicative Maintenance* leveraged a range of existing PG&E data sources to develop and deploy an industry-leading analytical model for identifying problems with distribution transformers with a high degree of accuracy. This model has been transitioned directly into operational use, has already led to numerous successful interventions, and is expected to save customers 1.2 million CMI per year and an associated $3.2 million per year in customer economic benefit by preventing outages caused by failed distribution transformers.

PG&E's proposed EPIC 4 Investment Plan will help California achieve energy and environmental policy goals, such as 100 Percent Clean Energy by 2045,[11] 100 Percent Zero-Emission Vehicles by 2035,[12] and Climate Change 2022 Scoping Plan[13]. PG&E's EPIC 4 plan also supports the Commission's key proceedings, such as Integrated Resources Plans[14], Development of Rates and Infrastructure for Vehicle Electrification (DRIVE)[15] and Climate Adaptation[16] to help inform these proceedings with learnings and data from demonstrations.

For the EPIC 4 investment cycle, these important California energy and environmental policy goals and Commission proceedings are represented in PG&E's investment plan as Strategic Objectives. Below, PG&E provides examples of our Strategic Objectives and how key policies and proceedings are supported through potential EPIC 4 advancements:

- PG&E Strategic Objective: Create a More Nimble Grid to Maintain Reliability as California Transitions to 100 Percent Clean Energy
    - Energy Policy Goal: SB 100: 100 Percent Clean Energy by 2045
    - Commission Proceeding: IRP

    This PG&E EPIC 4 Strategic Objective supports California achieving its energy policy goal of 100 percent clean retail energy sales from renewable energy resources by 2045 and the Commission's IRP proceedings to support the transition to delivery of clean energy by continuing innovation to enable reliable, resilient, renewable and affordable clean energy. The following are examples of advancements targeted by

11. SB 100, De León, Chapter 312, Statutes of 2018.
12. Executive Order (EO) N-79-20, 2020.
13. AB 32 requires the California Air Resources Board to develop a Scoping Plan that describes the approach California will take to reduce GHGs. The Draft 2022 Scoping Plan assesses progress toward the statutory 2030 target, while laying out a path to achieving carbon neutrality no later than 2045.
14. R.16-02-007.
15. R.18-12-006.
16. R.18-04-019.

PG&E's topics within this Strategic Objective that support these energy and environmental policy goals and proceedings:

- Ability to store vast quantities of renewable energy for long durations to ensure a reliable, affordable energy supply.
- Integration of emerging renewable generation technologies in a cost-effective, safe, and reliable manner.
- Microgrid technology and operational capability that can help mitigate capacity constraints, accelerate the adoption of new renewable generation and storage resources, and eliminate customer disruptions from PSPS and EPSS events.
- Enhanced system protection that is appropriate for a grid increasingly powered by inverter-based resources.
- Grid scenario planning tools that ensure that, over decades, the grid can evolve at a pace supportive of energy and environmental goals.

- PG&E Strategic Objective: Increase the Value Proposition of Distributed Energy Resources to Customers and the Grid
  - Energy Policy Goal: 100 Percent Zero-Emission Vehicles by 2035
  - Commission Proceeding: DRIVE

  This PG&E EPIC 4 Strategic Objective supports the California statewide target of 100 percent of passenger vehicle, off-road and drayage operation vehicle sales to be zero emission vehicles by 2035, and where feasible 100 percent of medium and heavy-duty vehicle sales to be zero emission vehicles by 2045. A key component of the Commission's DRIVE proceeding is helping the State achieve transportation electrification. PG&E provides the following examples of advancements within this Strategic Objective that support these energy and environmental policy goals and proceedings:

    - Ability to quickly and reliably interconnect the large and increasing amount of DERs, to enable transportation electrification and charging infrastructure buildout while avoiding delays associated with traditional capacity upgrades
    - Coordination and optimization of DERs by supporting the development of charging infrastructure, integrating EV load/grid support capabilities into grid planning, and working with technology providers to develop EV interoperability standards for the benefit of both customers and the grid.
    - Ability to effectively leverage electric vehicles as DERs and grid support resources when connected to the grid
    - Reducing the barriers to full transportation electrification, including but not limited to, the availability of a wider variety of EV charging options, the seamless interoperability for advanced V2X use cases, and an increase in the value proposition of EVs for customers through an EV battery second-life pathway.

- PG&E Strategic Objective: Guide California's Transition to an Equitable, Zero-Carbon Energy System that is Climate-Resilient and Meets Environmental Goals
  - Energy Policy Goal: AB: 32, Climate Change 2022 Scoping Plan
  - Commission Proceeding: Climate Adaptation

  This PG&E EPIC 4 Strategic Objective supports the State's goal to eliminate greenhouse gas emissions and become carbon neutral by 2045 as well as the Commission's Climate Adaptation proceeding to mitigate environmental impacts from climate change. PG&E provides the following examples of advancements within this Strategic Objective that support these energy and environmental policy goals and proceedings:

    - Demonstration of equipment and analytics technologies that prevent disasters that could result from extreme climate change-induced events.

- Ability to adopt climate and nature-positive operational methods, including, for instance, using the enormous volumes of woody biomass as a carbon sequestration opportunity for renewable natural gas or other value-added products.
- Demonstration of technologies and systems that enable our customers to reduce the environmental impact of their energy usage.

Stakeholder Engagement in the Investment Planning Process

This proposed EPIC 4 Investment Plan was developed through extensive internal engagement and through an open process including two workshops for the general public, two workshops for DAC representative groups, as well as numerous consultation meetings with the CPUC and CEC.

Internal: PG&E conducted extensive internal ideation for its EPIC 4 Investment Plan. First, PG&E solicited and collected hundreds of ideas in an open, bottom-up ideation process across the whole of the enterprise. These ideas were then grouped and aligned with the known technology and operational maturity gaps identified in PG&E's long-range planning and strategy initiatives. Each group of related ideas was then merged into a detailed narrative through an iterative process with the original idea submitters, other Subject Matter Experts (SMEs) and leadership, that ultimately resulted in the topics proposed in this application.

External: PG&E, along with SCE and SDG&E, conducted extensive stakeholder engagement for input on their respective EPIC 4 Investment Plans, including conducting four public workshops. The first public workshops included an initial overview of each Utility's proposed initiatives, presented with thematic panel-led discussions by the Electric Power Research Institute (EPRI)—an independent, non-profit organization recognized as a leader in conducting electric utility industry research and development. The second public workshop provided a more detailed review of each Utility's topics, presented thematically by Strategic Objective. Additionally, the IOUs held two targeted workshops with Disadvantaged Communities (DACs) to discuss how these communities can engage in each utility's EPIC 4 Investment Plan, understand these communities' challenges and priorities for technology innovation, and obtain feedback to inform the IOUs' EPIC 4 Investment Plans.

These workshops, as a whole, were well-attended with a broad spectrum of participants, including academia, industry, and research institutions, as well as environmental, customer advocates and community-based organizations. Table 1 summarizes the names and dates of each workshop.

Table 1: Stakeholder Events Held for EPIC 4 Investment Plan Development

EPIC 4 Public Event Title	**Date**
Joint Utilities EPIC DAC Workshop	June 21, 2022
Joint Utilities EPIC Public Workshop	June 30, 2022
Joint Utilities EPIC DAC Workshop	August 25, 2022
Joint Utilities EPIC Public Workshop	August 29, 2022

The IOUs also reached out to the Disadvantaged Communities Advisory Group (DACAG) and announced the joint IOUs DAC Workshops at the DACAG meetings. On August 19, 2022, the IOUs presented highlights of their draft EPIC 4 Investment Plans and explained how the initiatives would benefit DACs and under-resourced communities. The IOUs incorporated feedback from the DACAG into their second DAC Workshop to expand on how DACs and under-resourced communities can help provide feedback and shape EPIC 4 projects at project public workshops, following Commission approval of the IOUs' respective EPIC 4 Investment Plans.

PG&E has also applied the DACAG's Equity Framework to our EPIC 4 Investment Plan. The DACAG Equity Framework outlines the following key equity principles which have been adapted to our EPIC topics:

- **Health and Safety:** PG&E's EPIC 4 Investment Plan has a number of clean energy resources- and transportation electrification-related topics that will improve air quality for a positive impact on health. The air quality improvement will benefit all customers. Though as PG&E looks for opportunities to site specific demonstrations in DACs, there could also be a more direct, immediate benefit for those hosting communities. A number of topics in PG&E's EPIC 4 Investment Plan also increase resiliency or address climate change vulnerabilities, both of which would result in fewer outages and improve safety.

- **Access and Education:** PG&E encourages adoption of emerging technologies for grid advancement in DAC and under-resourced communities. As PG&E holds workshops for the projects that will result from the topics in its EPIC 4 Investment Plan, PG&E will conduct outreach to diverse stakeholders, help encourage community-based organizations to become key project partners, and support small and diverse businesses. PG&E plans to perform targeted outreach for its EPIC 4 project workshops to create meaningful engagement to help ensure demonstrations are applicable to community interests and responsive to these communities' needs.
- **Financial Benefits:** PG&E's EPIC 4 projects will help advance grid capabilities that provide financial benefits to disadvantaged and low-income communities such as by providing cost savings helping affordability. PG&E will put an emphasis, whenever possible, on locating EPIC 4 projects in DACs and other under-resourced communities to help improve energy equity.
- **Economic Development:** PG&E's demonstrations may support job growth for small and diverse businesses within DACs and under-resourced communities. PG&E's EPIC 4 projects also support economic development through working with diverse vendors as they continue to advance clean, emerging technologies applicable to the grid.
- **Consumer Protection:** Since the EPIC program places limits on the IOUs regarding the types of development and demonstration that can be done with EPIC projects, PG&E's projects do not directly address consumer protection. Nonetheless, PG&E's EPIC projects do indirectly support consumer protection through speeding the adoption of clean energy systems.

Although the DACAG's key equity principles apply to the whole of PG&E's EPIC portfolio, Table 2 specifically identifies which elements of the equity framework each topic is expected to support.

Table 2: EPIC 4 Equity Matrix

Topic #	R&D Topic	Health and Safety	Access and Education	Financial Benefits	Economic Development
1	Microgrid Enablement	●	●	●	●
2	Individual Customer Resiliency	●	●	●	●
3	Long Duration Energy Storage	●	●	●	●
4	Integration of New Generation Technologies	●	~~●~~	●	●
5	Grid Sensing and Communication	●	●		●
~~6~~	~~Grid Scenario Planning~~			~~●~~	
7	Advanced Drone Applications	●			
8	Advanced Predictive Maintenance and Failure Cause Analysis	●	●		●
~~9~~	~~Work Management~~	~~●~~		~~●~~	
10	System Protection	●			
11	Interconnection Enablement	●	●	●	●
~~12~~	~~Advanced Distribution Power Flow Management~~	~~●~~		~~●~~	
13	Electric Vehicle Charging and Integration Enablement	●	●	●	●

14	Electric Vehicle Battery Re-Use for Stationary Energy Storage	●		●	●
15	Preventing Faults from Causing Ignitions	●			
16	Undergrounding Capabilities	●	●	●~~○~~	●
~~17~~	~~Improved Inspection Capabilities~~	~~●~~		~~○~~	
~~18~~	~~Pinpointing Fault Location~~	~~●~~			
19	Risk Modeling Improvements	●		~~○~~	
~~20~~	~~Crowdsourcing~~	~~●~~		~~○~~	
21	Climate and Nature-Positive Operations	●	●		●
22	Disaster Protection	●			
23	Granular Attributes for Environmental Commodity Tracking	●	~~●~~	~~○~~	

Legend for Equity Principles:
● = Direct Benefits
~~○ = Indirect Benefits~~

Through the extensive public engagement and the ongoing collaboration amongst the four EPIC Administrators, it became clear that the Administrators' plans proposed to address many related challenges and opportunities. Now that, in the EPIC 4 cycle, the IOUs' plans are no longer being filed at the detailed project level, and instead being filed as sets of higher-level topics, this is to be expected, as there are similarities among the IOUs in the architecture and operation of their systems, the challenges they face, the overarching state goals they are accountable for addressing, and their associated technology development and demonstration needs. Topic areas that overlap are broad and will require a range of solutions that warrant numerous technology demonstrations, and the Administrators will coordinate closely in their project planning to ensure that individual projects avoid unnecessary duplication, ensure robust information sharing, and complement related activities.

Strategic Framework and Budget

Throughout 2022, PG&E developed a strategic framework to help guide the planning for its EPIC 4 Investment Plan. The framework consists of three strategic objectives. The strategic objectives and five associated underlying initiatives are a subset of those in the CEC's EPIC 4 Investment Plan and are the framework under which PG&E's 23 distinct investment topics have been proposed.

The EPIC strategic framework seeks to:

- Guide PG&E's planning and implementation of its EPIC program through the remainder of this investment plan cycle.
- Communicate a consistent set of priorities to stakeholders.
- Illustrate how projects funded through EPIC are building toward an electricity system that meets state energy policy goals.
- Help simplify strategic alignment of PG&E's EPIC investments with its fellow EPIC Administrators, as well as other public energy research programs and policies.

Chapters 2 through 4 of this investment plan provide an overview of each strategic objective and associated initiatives. These chapters then describe PG&E's 23 underlying RD&D topics proposed for funding through the EPIC 4 investment plan cycle. Our three strategic objectives and five initiatives for EPIC 4 are listed Table 3 below. Table 3 also provides the proposed budget allocation for EPIC 4 funding at the initiative level, as well as the proposed administrative budget and PG&E's portion of the oversight budget to be remitted to the CPUC.

PG&E does not have uncommitted EPIC 3 program funds with which to offset its EPIC 4 program budget.

Table 3: PG&E EPIC Funding 2022–2025

Funding Item	Amount
Strategic Objective: Create a More Nimble Grid to Maintain Reliability as California Transitions to 100 Percent Clean Energy	
Initiative: Clean, Dispatchable Resources	$18,000,000
Initiative: Grid Modernization	$18,000,000
Strategic Objective: Increase the Value Proposition of Distributed Energy Resources to Customers and the Grid	
Initiative: Distributed Energy Resource Integration and Load Flexibility	$18,000,000
Initiative: Transportation Electrification	$11,453,075~~10,953,075~~
Strategic Objective: Inform California's Transition to an Equitable, Zero-Carbon Energy System That Is Climate Resilient and Meets Environmental Goals	
Initiative: Climate and Environment	$17,500,000~~18,000,000~~
Administration and Oversight	
CPUC Oversight Budget	$463,425
PG&E Administrative Budget	$9,268,500
Total	**$92,685,000**

CHAPTER 2: Create a More Nimble Grid to Maintain Reliability as California Transitions to 100 Percent Clean Energy

PG&E's electric system will undergo substantial changes as it transitions away from reliance on the remaining large fossil-fueled power plants and moves toward a grid dominated by intermittent renewable and distributed generation, as well as energy storage systems, to deliver 100 percent renewable and zero-carbon electricity. The grid will need to become more flexible, with different resources, and with greater control over when, where, and how much energy flows.

EPIC RD&D will play an important role, both by developing technologies to help maintain electric reliability and resilience and creating modeling and decision tools to identify tradeoffs and optimal deployment strategies for the coming decades. The topics described in the chapter fall under two initiatives: Clean, Dispatchable Resources; and Grid Modernization. The topics will help develop the technologies and modeling capabilities that will enable a more flexible electric grid, that is able to meet our customers' needs, reliable, cybersecure, and decarbonized. PG&E is collaborating with ~~the its~~its fellow EPIC Administrators as they share this same strategic objective. For certain of the CEC's and PG&E's topics, PG&E will closely collaborate with the CEC and potentially conduct joint projects, working together per our respective roles on the support, development, interconnection, operation, and analysis that will be important for delivering the full benefits of the related research and demonstration.

Clean, Dispatchable Resources Initiative

Clean, dispatchable resources will be foundational to achieving PG&E's and California's clean energy and environmental goals. Microgrids are a key technology area as they offer services to both customers and to the grid, providing reliability, resiliency, capacity constraint mitigation, and emissions-free electric service. In particular, individual customers with critical power needs or that are most affected by PSPS and EPSS events are in need of increased resiliency. Long duration energy storage at a lower cost and of greater size will also be key to delivering clean, dispatchable power throughout the year and through extreme climate conditions. In addition, PG&E needs to learn how to interconnect, and then safely and efficiently operate new types of emerging generation technologies.

1. Microgrid Enablement

Innovation Need

Microgrids offer promising solutions for California electric customer needs—they can make electricity service for remote areas significantly more reliable, reduce or eliminate disruptions caused by PSPS and EPSS events, help mitigate capacity constraints, provide emissions-free service, and in some instances also reduce wildfire risk. While PG&E has begun to develop foundational microgrid capabilities through its EPIC 3 program, many technical issues remain unresolved, including the protection schemes for various microgrid topologies, incorporation of EVs and temporary mobile batteries, alternate generating sources and settings (fuel cells, EVs, new energy storage technology, hydrogen-fueled gensets, etc.), islanding and synchronization, repeatability, and flexibility of microgrid location (within the feeder geographical space as well as service to DACs and critical areas within the grid). Recognizing the forthcoming dominance of renewable energy resources as a microgrid power supply suggests that safely and reliably operated microgrids, in all their different topologies, will be critical for PG&E and the state of California to meet their goals.

Description

Presently, every microgrid is a unique design, and not repeatable. To help create repeatable designs, PG&E will first define a set of microgrid architectures that accommodate the bulk of the current and emerging microgrid needs, defined by, for example, purpose, size, generation and storage types, interconnection type, interconnection location, islanding type and duration as well as load de-energization and critical loads supported. The microgrid designs will then be modeled, followed by laboratory testing of new components or new applications of existing components. Finally, one or more of the microgrid designs will be constructed, permitted, and demonstrated to the satisfaction of PG&E’s operations staff and the microgrid owners.

PG&E will seek definitive answers on the following:

- Criteria for when to create a permanently islanded (remote grid), including down to the size of a single residential customer
- Analysis of where microgrids would be most beneficial to reducing localized grid stress
- How to best mitigate the growing power quality and harmonics issues from increasingly inverter-based resources in microgrids
- Black start capability of inverter-based microgrids
- How best to leverage behind-the-meter (BTM) generation, storage, and load curtailment in microgrid operation
- How customers can be compensated for supporting the microgrid through their BTM generation and storage, as well as for responding to load curtailment requests.
- How to best communicate to get settlement-quality metering data from BTM inverters and storage
- Where and how to build microgrids at various locations on a feeder, from the end of the feeder up to and including at a substation
- How to best operate the grid through all of the states of the connected microgrid, including intentional and unplanned islanding, the operation of the microgrid including front-of-the-meter (FTM) and BTM resources
- Alternative clean generating sources and settings for the microgrid use case
- How mobile batteries (including but not limited to mobile batteries on PG&E service trucks) should be best utilized to connect into the pre-existing interconnection hubs on microgrids for islanded grid support during PSPS, EPSS, or other grid outage scenarios.
- When and how to incorporate novel wireless power transmission capability into microgrids, for emergency or permanent use
- When and how to create a service-transformer-located multi-customer microgrid

The fellow EPIC Administrators have begun coordinating and will continue coordinating on activities in this broad area to ensure demonstration coverage of promising microgrid types and technologies, to avoid duplication, and to ensure effective information sharing. In addition, beyond conducting its own projects on various microgrid architectures and technologies through this topic, PG&E will potentially partner with the CEC to conduct joint projects, in which the CEC's projects fund the development and configuration of the microgrid, and corresponding PG&E projects focus on enabling the integration and testing of the microgrid. This model has already proven to be successful in the microgrid space, where PG&E and the CEC executed complementary projects to operationalize the Redwood Coast Arcata Microgrid (RCAM), the first multi-customer microgrid in PG&E's service area.

Expected Outcomes

This topic will provide the following outcomes:

- A playbook of standardized microgrid designs that would help speed implementation and interconnection
- Understanding of how to safely and reliably operate the various standardized microgrid types
- Enhancements to the microgrid equipment test lab at PG&E's Applied Technology Services (ATS) facility to enable testing of the various microgrid designs
- Evaluations of new and/or novel equipment required to safely support the various new and emerging topologies, such as reclosers/controllers, inverters, new meter technology, FTM energy storage including temporary energy storage, as well as BTM generation, storage including EVs, and load control systems
- Confidence in new and novel microgrid-appropriate generating technologies, such as hydrogen or propane-based generation
- Confirmation of system protection configurations and operating parameters
- Deep knowledge of microgrid impact on the PG&E distribution grid and matching mitigation measures through modeling
- Installation, integration, and demonstration of one or more microgrids incorporating new or novel technologies

Metrics and Performance Indicators

- Number of standardized microgrid topologies

- Number of days from inception of new microgrid to permitted operation

Primary Users and Beneficiaries

- **Customers** will benefit from the ability to have reduced PSPS, EPSS, and other grid outage durations, and increased reliability due to microgrid implementation.
- **IOUs** will benefit by advancing customer choice in generation and satisfying a pent-up need for more rapid deployment of microgrids.
- **Grid operators** will benefit from this topic by playing a large role in moving towards standardizing the operational expectations of all topologies of microgrids.
- **Regulators and planners** will benefit by getting an increasing amount of low-carbon generation onto the grid. Planners will benefit by a deeper understanding of the system requirement for widespread deployment of microgrids.
- **Disadvantaged and under-resourced communities** in the wildland urban interface will benefit from improved reliability and safety as PG&E will target such ~~vulnerable or disadvantaged~~vulnerable, disadvantaged or low-income communities for demonstrations.
- **Technology developers and manufacturers** will benefit from the trialing of new technologies appropriate for microgrid customer acceptance.

Guiding Principles

- **Safety:** Uninterrupted power provided by a microgrid during times of PSPS, EPSS, and other outages avoids unsafe situations that can arise from lack of power.
- **Reliability:** Reliability is enhanced by the ability to island which reduces or eliminates the impact of PSPS, EPSS, and other grid outages.
- **Affordability:** Delivering common microgrid designs with a complete understanding of siting issues with regard to the grid will deliver lower-cost solutions to microgrid owners.
- **Environmental Sustainability:** Most participants in the microgrid market (suppliers, customers, communities, utilities) base their microgrid design on providing renewable energy.

- **Equity:** DACs, vulnerable, and under-resourced communities in the wildland urban interface will benefit from demonstrations targeted for those locations. Uninterrupted power provided by a microgrid during times of PSPS, EPSS, and other outages avoids potential loss of healthcare, education, childcare, and work. This type of energy resiliency can have positive impacts on health and safety, access and education, financial benefits, and economic development.

Background, Previous Research, and Technology Trends

The Redwood Coast Airport Microgrid (RCAM) funded through complementary PG&E and CEC EPIC 3 projects provides an excellent template for understanding how to advance the state of the art for a broader set of use cases. That project paired two groups (the Owner/Operators of RCAM and PG&E) who were committed to working together in full recognition that there would be many complex issues to resolve. Microgrids are not uncommon in the United States, but still make up a very small fraction of the overall generation. The number of configurations is also currently quite small and each microgrid requires extensive custom design, engineering and testing efforts. To increase the pace of deployment, key technical issues such as generation supply, islanding protocols, system protections, coordination of conventional generation with inverter-based generation need to be addressed. Resolving these issues provides a pathway to standardization, which will dramatically increase the pace of microgrid installations.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	**Topic Applicable**
Grid Operations/Market Design	●
Generation	●
Transmission	
Distribution	●
Demand-Side Management	●

2. *Individual Customer Resiliency*

Innovation Need

In response to increasing wildfire risk in recent years, PG&E has formalized a program for implementing Public Safety Power Shutoffs (PSPS) in high fire threat areas within its service area when wind and other environmental conditions exceed pre-defined risk thresholds. In 2021, PG&E also began broadly modifying the settings and increasing the sensitivity of its existing protective devices through its Enhanced Powerline Safety Settings (EPSS) initiative, to automatically de-energize powerlines when potential problems are detected. EPSS operates under a far broader set of environmental conditions as compared to PSPS, including on “blue sky” days. While PSPS and EPSS significantly reduce wildfire risk, they also result in increased outages for customers, and sometimes, a series of unplanned outages for groups of customers over the course of a wildfire season. PSPS outages tend to be longer than EPSS outages, however the unplanned nature and frequency of EPSS outages can be very disruptive to customers.

While PG&E has focused several customer programs on providing commercially available reliability solutions that reduce customer impacts of PSPS and EPSS for a small number of individual customers using Distributed Energy Resources (DERs), there is a need to demonstrate new innovative, scalable, clean technologies as well as the ancillary tools to support the technologies, and address deployment barriers.

Description

This topic will conduct technology demonstrations and path to production activities for a range of clean mobile and stationary DERs to provide greater resiliency at lower costs for individual residential and non-residential customers impacted by PSPS and EPSS events. The work within this topic will focus on three areas:

1. Resiliency DER Technology Development: Enhancing the availability of clean mobile and stationary distributed energy resources (DERs) that can be used to support individual customer resiliency.

2. Resiliency DER Ancillary Tools: Demonstrating innovations in the ancillary tools needed to deploy Resiliency DERs, as well as provide the foundation for enabling multiple other uses and enabling broader benefits. Ancillary tools will include things such as controls, meter connection, and automatic transfer switches.
3. Broader Operational Considerations: Enabling opportunities and addressing barriers to leveraging Resiliency DERs to provide additional value to the energy grid and to customers. Work in this area will be coordinated with Topic 12, “Advanced Distribution Power Flow Management”. Enabling broader value streams will help to accelerate adoption of vehicle and building electrification and enable Resiliency DERs to help support energy affordability for all Californians.

This topic could directly benefit more than one million of PG&E’s electric customers. It will explore solutions and challenges for a range of use cases by type of customer, and frequency and duration of outage impacts that need to be mitigated.

Residential customers impacted by outages include customers living in single family homes, multifamily complexes, mobile home parks and other residences. Examples of non-residential customer types that would benefit from the results of this topic include critical facilities customers, including K-12 schools, gas stations, grocery stores, food banks, and local public safety, medical, and other critical infrastructure[17].

The optimal solutions may be combinations of technologies that vary by use case and customer type. For example, the best solution for customers affected by more frequent but shorter EPSS impacts may differ from the best solution for those affected by less frequent but longer PSPS impacts. The solutions may also be for a PSPS or EPSS event or for a single season until other mitigations can be applied. The best solution will also depend on the types of BTM DERs customers may already have.

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17. PG&E Critical Facility Customer Fact Sheet: https://www.pge.com/pge_global/common/pdfs/safety/emergency-preparedness/natural-disaster/wildfires/CWSP-Critical-Facility-Customer-Fact-Sheet.pdf.

For all the solutions to be demonstrated, the primary purpose is to provide individual customer resiliency, though grid support could also be provided to further increase the value proposition of the DERs to customers. This work will be coordinated with the work in other topics, such as what has been proposed through Topic 12, “Advanced Distribution Power Flow Management”. Topic 2, “Individual Customer Resiliency”, would also explore how the potential increase in value to the customer of also using their Resiliency DERs for other grid support use cases could make adoption more economically viable, thus helping to speed customer resiliency improvements in aggregate.

Expected Outcomes

The following are outcomes expected to result from the demonstrations conducted through this topic:

- Technology Development
  - Operational demonstrations of various combinations of temporary and permanent resiliency DERs with limited sets of customers
  - Testing and evaluation of new battery and clean generation technologies for the resiliency use case
  - Improvements to existing product offerings based on field demonstrations
  - Benchmark various DERs– performance, safety, construction, and battery cell quality for both portable and permanent battery storage
- Ancillary Equipment
  - Identification, operational investigation including for liability considerations, and demonstration of innovative and emerging resiliency use case solutions such as backup power transfer meters, smart panels, microinverters, smart thermostats, load control, and vehicle-to-building (V2B) equipment
  - Reductions in installation and deployment costs
- Deployment Support
  - A playbook for how to package solutions for the various customer use cases

    - Recommendations for updates to standards and work methods needed for the safe application and operation of these solutions
    - Understanding of the costs and benefits of these solutions per use case in comparison to potential alternatives
    - Identification of opportunities to leverage non-ratepayer funding (federal, state) to increase deployment and support affordability
    - Understanding of operational considerations of using mobile battery technology (EV) as a backup power source for a customer's dwelling on thresholds of charge to maintain on the EV in case they need to evacuate

Metrics and Performance Indicators

- Percent of customers that experience PSPS and EPSS events that are made invisible to customers through the various solutions demonstrated through this topic
- Number of aggregated kWh available
- Number of solutions for particular use cases successfully demonstrated and included in customer incentive programs
- Cost per customer mitigation across various customer types to enable cost-effective mitigations
- Tons of emissions that could be avoided through the deployment of the solutions demonstrated through this topic by offsetting non-clean generation and providing reliability benefits

Primary Users and Beneficiaries

- **Customers** in high fire risk areas will benefit from improved reliability and lessened impact or elimination of impact from PSPS and EPSS events. This includes but is not limited to customers who have electricity-dependent medical equipment. Leveraging customers resiliency solutions for multiple uses may also reduce costs, supporting energy affordability for all customers. Customers may also benefit from lower local emissions from reduction or elimination of fossil fuels generators operating in the area.

- **IOUs** will have additional solutions to offer their customers to mitigate the impacts of the PSPS and EPSS initiatives they implement.
- **Local governments** will have increased resiliency in critical facilities and lower electrical-outage-related service calls (medical, public safety-related) and lowered impact on local business and residents from power outages.
- **Under-resourced communities** in high fire risk areas will benefit from improved reliability and lessened impact of PSPS and EPSS events.
- **Technology developers and manufacturers** may improve their product offerings based on the results and learnings of the demonstrations.

Guiding Principles

- **Safety**: Reduction of the risk of fire from improperly connected customer fossil fuel generators and customer-supplied portable lithium batteries subject to thermal runaway. In addition, a reduction of the hazards of localized pollution from gasoline or diesel generators, and prevention of back feeding of energy onto the grid from unauthorized installations.
- **Reliability:** The innovative technologies demonstrated in this project will help to lessen the individual customer outage impacts of PSPS and EPSS events.
- **Affordability:** Pre-packaged, repeatable solutions at the right size to fit the use case will reduce customer costs.
- **Environmental Sustainability:** The innovative technologies demonstrated in this project will provide clean alternatives to diesel generators widely used for customer resiliency.
- **Equity:** The innovative technologies demonstrated in this project will help to lessen the outage impacts to specific communities of customers in high fire risk areas that are disproportionately impacted by PSPS and EPSS events. Localized pollution impacts from diesel generation would be eliminated. Additionally, uninterrupted power provided by DERs and mobile clean energy sources during outages avoids potential loss of healthcare, education, childcare, and work. This type of energy resiliency can have positive impacts on health and safety, access and education, financial benefits, and economic development.

Background, Previous Research, and Technology Trends

PG&E and other entities offer a variety of resiliency programs that provide customers resiliency solutions through portable or permanent solutions. PG&E also provides temporary generation to critical customers, as described in its Wildfire Mitigation Plan. PG&E has also worked with a variety of solutions to reduce the costs and increase the viability of Resiliency DERs including the Backup Power Transfer Meter (BPTM) that PG&E developed and piloted for diesel generator backup, and a variety of efforts that explored smart panels and other tools to help customer resiliency. At the same time, Virtual Power Plants (VPP) and other interventions have demonstrated the ability of DERs to provide grid reliability.

However, there are a large number of customers that are not able to be mitigated due to outages, due to the size of their load, restrictions around their premise (for example renters) and the lack of resources (financial and others). This topic will build on existing knowledge to accelerate solutions that can meet the significant needs around customer resiliency and grid reliability in the face of accelerating climate change to enable scalable deployment of clean resiliency solutions to a much larger number of customers.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	●
Generation	
Transmission	
Distribution	●
Demand-Side Management	●

3. Long Duration Energy Storage

Innovation Need

Advancements in long duration energy storage (LDES) technologies, defined as having a minimum discharge duration of eight hours or longer, are required to maintain reliability and affordability as the state transitions to a 100 percent renewable, zero-carbon electricity system. The capacity challenges California faced in each of the past three summers reinforced the urgent need for additional LDES resources. The CPUC estimates that California will need 1,000 MW of LDES resources by 2030 and the 2021 SB 100 Joint Agency Report[18] indicates that by 2045 the state may potentially need upwards of 4,000 MW of additional LDES resources. LDES, which can discharge over days, weeks, or even seasons, is expected to not only address some of the issues created by weather patterns for which short duration energy storage is insufficient or cost-prohibitive, but also to balance long-term variations in renewable generation created by large weather patterns and changing seasons. Additionally, LDES resources could potentially be used to provide local resilience during extended grid outages.

Apart from conventional pumped hydroelectric storage ("pumped hydro"), neither the technologies nor the business models of other LDES solutions have been proven ready as grid-scale resources. Pumped hydro faces challenges in permitting and has limited potential for expansion due to a lack of suitable sites in California. In recent years, the CEC and other entities have funded the development of a wide range of LDES technologies. Many of these technologies have matured and begun to show viability in lab demonstrations as well as in limited operational behind-the-meter (BTM) demonstrations at customer facilities. Building from previous laboratory and limited BTM field testing of promising LDES technologies, additional demonstration activity is required for PG&E to develop practices and experience to safely interconnect and integrate larger-scale front-of-the-meter (FTM) LDES deployments.

18. SB 100 Joint Agency Report: Charting a Path to a 100 percent Clean Energy Future. California Energy Commission. https://www.energy.ca.gov/news/2021-03/california-releases-report-charting-path-100-percent-clean-electricity.

Description

This topic will support the FTM installation, demonstration, and grid integration of various LDES solutions that enable the storage of renewable energy for discharge durations of eight to hundreds of hours or longer, and inform resource planning, characterize safety profiles, and provide knowledge of integration and operational considerations. PG&E will focus on demonstrating promising, scalable LDES solutions that have matured and successfully progressed through preliminary lab demonstration through the CEC's EPIC program and elsewhere. Examples of the types of LDES solutions that may be demonstrated include flow batteries, kinetic, thermal, compressed air, liquid air, hydrogen produced from renewable energy, and gravity storage. Prior to interconnecting LDES systems to the grid, PG&E may first validate their operational performance capabilities including discharge profiles, differences from short duration energy storage systems, and compare the systems' relative strengths and weaknesses at its Applied Technology Services (ATS) lab facilities to down-select systems for demonstration on the grid and develop grid integration plans.

Demonstration of use cases will include firming of intermittent renewable generation, providing resilience during PSPS or EPSS events and other grid disruptions, and market participation for energy arbitrage (i.e. flattening the "duck curve"[19]). PG&E would support CAISO and other stakeholders in establishing the framework and technical requirements to enable properly incentivized LDES market participation. PG&E will consider selecting sites for demonstrations that will allow for the co-location of LDES systems with existing intermittent renewable generation, as well as potentially other sites that are better suited to specifically mitigating the effects of PSPS and EPSS outages.

The fellow EPIC Administrators have established bi-weekly coordination meetings on LDES and other technology areas that have significant opportunities for collaboration. Through these meetings, the EPIC Administrators share information on past projects and future investment priorities. Furthermore, the EPIC Administrators are evaluating opportunities and process requirements for formal partnerships on projects and to avoid duplication. For example, PG&E

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19. https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf.

and CEC could potentially conduct joint projects in which CEC EPIC funding supports LDES technology development, acquisition, and configuration with PG&E EPIC funding supporting testing and grid interconnection in ways that are safe, replicable, and scalable. Additional strategies include identifying specific demonstration site locations based on PG&E knowledge of local grid conditions and needs prior to the CEC releasing competitive bid solicitations for technology demonstrations. This model for CEC and PG&E collaboration has proven successful in the microgrid space, where PG&E and the CEC executed complementary EPIC projects to operationalize the Redwood Coast Airport Microgrid (RCAM), the first multi-customer microgrid in PG&E's service area.

Expected Outcomes

Expected outcomes from the demonstrations pursued within this topic include:

- Definitive assessment of the readiness, safety profiles, and interconnection considerations of various LDES solutions for FTM grid deployment at scale
- Selection of a subset of solutions for FTM demonstration
- Installation, integration, and operational safety testing of one or more LDES systems
- Transfer of installed systems to steady-state post-EPIC operations, with post-EPIC funding
- Development of a roadmap, strategy, and implementation plan for broader future Utility and/or third party LDES acquisition, deployment, and grid integration

Metrics and Performance Indicators

- Demonstration of safe and reliable operation of LDES systems
- Number and total MWh of LDES systems successfully installed on the grid and transitioned to steady-state post-EPIC operations
- Availability of standardized market models and integration methods for LDES

Guiding Principles

- **Safety**: This topic will demonstrate LDES technologies that eliminate or mitigate safety risks such as thermal runaway.

- **Reliability**: LDES can play a critical role in ensuring electric reliability across long periods of low renewable generation and even across seasons.
- **Affordability**: Demonstration of emerging LDES technologies will target cost reductions that support electric service affordability.
- **Environmental Sustainability**: Implementation of non-lithium-ion storage technologies can increase supply chain diversity, reduce reliance on critical materials, and prove end-of-life recyclability or benign disposal.
- **Equity:** Reliable electricity supply, supported by long duration energy storage during outages, avoids potential loss of healthcare, education, childcare, and work. This type of energy resiliency can have positive impacts on health and safety, access and education, financial benefits, and economic development.

Primary Users and Beneficiaries

- **Customers** will benefit from the reliability benefits that LDES provides in the transition to a 100 percent renewable and zero-carbon energy grid, as well as the financial benefits of energy price arbitrage through LDES market participation.
- **IOUs** will benefit from solutions that will enable them to maintain affordable and reliable service in a transition to a 100 percent renewable and zero-carbon energy grid.
- **CAISO** will benefit from advancements in larger-scale FTM LDES technologies that mitigate potential generation shortages and operational challenges due to the seasonal variability of wind and solar.
- **Regulators and planners** can use the results from this topic to integrate LDES assets within grid planning and procurement decisions to achieve state energy goals.
- **Policymakers** can use the results from this topic to assess the effectiveness of policies to retire remaining fossil fuel generation, increase the use of renewable energy to meet SB 100 goals, and reduce total system costs.
- **Technology developers and manufacturers** will benefit from targeted opportunities to demonstrate, improve, and build market confidence that their technologies enable safe, reliable, affordable electric service with reduced environmental impacts.

~~Guiding Principles~~

- ~~**Safety**: This topic will demonstrate LDES technologies that eliminate or mitigate safety risks such as thermal runaway.~~
- ~~**Reliability**: LDES can play a critical role in ensuring electric reliability across long periods of low renewable generation and even across seasons.~~
- ~~**Affordability**: Demonstration of emerging LDES technologies will target cost reductions that support electric service affordability.~~
- ~~**Environmental Sustainability**: Implementation of non-lithium-ion storage technologies can increase supply chain diversity, reduce reliance on critical materials, and prove end-of-life recyclability or benign disposal.~~

Background, Previous Research, and Technology Trends

While energy storage is one of the fastest growing markets in the world, lithium-ion technologies comprise the vast majority of the market and are generally not well suited to LDES applications. As global commitments to achieve zero-carbon electricity systems accelerate, many countries are evaluating LDES technologies as an alternative to fossil fuel-powered "peaker" plants. Although LDES technologies account for a low fraction of storage deployed to date, it is expected and necessary that installations increase significantly.

The CEC's EPIC program has supported the development of LDES for the past several years, providing a foundation and maturity for potential Utility involvement in FTM demonstration in an operational grid environment. Data collected through the CEC's projects will help inform how LDES assets are operated and what additional benefits they provide beyond short duration energy storage.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	●

Generation	
Transmission	●
Distribution	●
Demand-Side Management	

4. Integration of New Generation Technologies

Innovation Need

Solar photovoltaic (PV) and onshore wind technologies provide mature and well-established methods for renewable electricity generation, but there is a range of emerging and promising generation technologies that will require grid integration and demonstration to better understand their value proposition and potential use cases. While PG&E's EPIC 4 Topic 1, "Microgrid Enablement", proposes to include demonstrations of emerging clean generation technologies as part of microgrid applications specifically, and PG&E's EPIC 4 Topic 3, "Long Duration Energy Storage", proposes to include demonstrations of emerging LDES technologies, there is still a much broader range of emerging generation technologies and potential use cases (e.g. distribution/substation/local transmission capacity, system energy capacity, resilience), that will continue to mature over the coming years and require grid demonstration in the EPIC 4 timeframe.

Description

This topic will conduct grid demonstrations of a range of emerging technologies for electricity generation, to better understand their value proposition and potential use cases and inform pathways for operational deployment. PG&E will not fund the development of the underlying emerging technologies, but rather demonstrate promising candidates as they emerge from the CEC's EPIC program and other applied R&D programs. PG&E will coordinate closely with the CEC as their earlier-stage investments in a range of technologies progress, to identify opportunities to execute partner projects in which the CEC's grants fund the procurement of the new generation systems and PG&E's projects fund PG&E's involvement in integrating these solutions into the grid. Furthermore, technology vendors may be able to access other funding sources such as direct Federal and state grants, and private institutions, and the utilization of EPIC funds will allow such technologies to be interconnected on the grid as a proving ground. Examples of generation technologies to be demonstrated include, but are not limited to, hydrogen, fuel cell, novel geothermal, linear generators, offshore wind, emerging solar PV technologies, and potentially others.

Expected Outcomes

The demonstrations pursued through this topic are expected to result in the following outcomes:

- Grid integration (e.g. engineering design, protection, operations) and demonstration of one or more emerging generation technologies for transmission, substation or distribution use cases
- Validation of combinations of specific technologies and use cases, and development of plans for broader post-EPIC implementation
- Identification of performance requirements to influence future improvements to vendors' product offerings

Metrics and Performance Indicators

- Demonstration of safe and reliable operation of new generation technologies
- Number and total MWh of new generation technology systems successfully installed on the grid and transitioned to steady-state post-EPIC operations
- Availability of standardized market models and integration methods for new generation systems

Primary Users and Beneficiaries

- **Customers** will benefit from the positive environmental impacts of the renewable generation technologies enabled through this topic, as well as potentially reduced bills associated with an overall more cost-effective generation portfolio.
- **IOUs** will benefit from the availability of additional technologies with which to achieve their own and California's climate goals.

- **Regulators and planners** will benefit from knowing the most cost-effective ways of integrating new generation technologies at utility scale.
- **Under-resourced communities** may benefit directly from renewable generation technologies installed and demonstrated within their communities as part of demonstration projects within this topic.
- **Technology developers and manufacturers** will benefit from the learnings of demonstrations which may serve to inform enhancements to their product offerings.

Guiding Principles

- **Safety:** The renewable technologies enabled through this topic may help inform how protection schemes, fuel safety, and other operational considerations need to be established to ensure that they can be operated safely on the grid.
- **Reliability:** The renewable technologies enabled through this topic may help PG&E maintain grid reliability in its transition to 100 percent clean energy.
- **Affordability:** The renewable technologies enabled through this topic may be significantly more cost-effective than current solutions for transitioning to 100 percent clean energy.
- **Environmental Sustainability:** The renewable technologies enabled through this topic will help to reduce the emissions from electricity generation.
- **Equity:** The renewable technologies enabled through this topic may provide viable substitutes for non-renewable forms of generation either located in or directly impacting DACs and other vulnerable communities. Increased renewable and clean energy technology in these communities can have positive impacts on public health by reducing or eliminating pollutants from local fossil fuel power plants and/or local diesel generators. Additionally, EPIC can help support local financial benefits and economic development within DACs by partnering with community-based organizations during demonstrations. Partnerships through EPIC can accelerate local expertise and organizational capacity in an emerging technological area.

Background, Previous Research, and Technology Trends

As mentioned above, solar PV and onshore wind technologies provide mature and well-established methods for renewable electricity generation, but there is a range of emerging generation technologies that are being funded and matured, that will ultimately require grid integration and demonstration to better validate their value proposition, inform potential use cases, and help establish roadmaps to broader grid implementation. The CEC has dedicated an entire strategic objective in their EPIC 4 plan to "Accelerate Advancements in Renewable Generation Technologies", which will fund the maturation of new solar photovoltaics, offshore wind, and geothermal energy generation technologies. PG&E will monitor the progress of candidate technologies as they emerge from the CEC's EPIC program and other applied R&D programs, in ultimately selecting a subset that are ready for direct utility involvement and grid demonstration to advance the technologies.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	●
Generation	●
Transmission	●
Distribution	●
Demand-Side Management	

Grid Modernization Initiative

Beyond increasing microgrid development, resiliency, flexible zero-carbon generation and storage resources, there must continue to be advancements to the grid itself and its operation in areas such as monitoring, protection, maintenance, and planning. Many types of new sensors and a significantly enhanced communication system are needed to operate the grid safely and reliably through significant ongoing change. Better planning tools are needed to make informed investment decisions around grid architecture over the coming decades in the face of several trends disrupting the current grid architecture. New methods of aerial surveillance, predictive maintenance and more efficient and transparent ways of executing complex work products are needed, and with the rapid increases in the types and location of DERs on the grid, the way that the grid is protected needs to change. This Grid Modernization initiative addresses these needs.

5. Grid Sensing and Communication

Innovation Need

For PG&E to reliably, safely, and efficiently operate the grid of the future, there will need to be deployment of 1) many new sensor types; 2) edge computing to analyze data streams and make autonomous and coordinated control decisions; 3) advanced, pervasive cybersecurity protection; 4) support for far greater data volumes; and 5) a flexible, pervasive, multi-use communication system. There are many new technologies of interest that may address parts of these needs, though many unanswered questions remain about those technologies and how to create a comprehensive whole that addresses all of PG&E's distinct needs together.

Description

This topic will demonstrate new sensing technologies that could significantly advance PG&E's safety, reliability, and affordability goals related to a range of initiatives for wildfire prevention, asset protection, and grid operations. New sensors will generally first be tested in a laboratory setting and then, if successful, installed and demonstrated in a limited number of field sites. Examples of sensors that may be demonstrated include:

- Advanced service meter "grid sensor" including but not limited to sensing compromised neutrals/floating voltages, local grid disturbances, advanced power quality, advanced power flow, grid health, momentary outages, local grid topology, phase detection, and earthquakes.
- Animal/bird strike sensor

- Acoustic camera that can identify leakage currents and degraded components on distribution lines
- Insulator soiling/debris sensor to inform predictive wash schedules, taking into account weather/rain and other factors
- Earthquake detection sensor for reclosers
- Pole and attached equipment health sensors (e.g. inclinometer for tilt, accelerometer for vibration)
- Combined economic packaging of micro weather stations, infrared, acoustic, visual, LiDAR and other sensors, including the other sensors mentioned here
- Long-range high-resolution flame detectors
- Gas sensors and AI to detect smoking/smoldering transformers, capacitor banks, utility poles or other utility equipment
- Additional sensors and use cases that inform predictive analytics to support a proactive asset management model for the distribution system, including investigating the risk-informed prudence of setting end-of-life limits for certain types of grid equipment (e.g., transformers).

This topic will also provide insight into and demonstrate communications options of a highly interconnected utility. Projects will demonstrate technologies needed to create a unified communications platform that includes support for many millions of communicating devices across a wide range of emerging communication media, with a common cybersecurity system, and the resiliency features needed to continue operating while degraded or in times of emergency. The technology demonstrations will also address PG&E's distinct communications challenges related to rugged, remote areas and steep canyons, and need for edge computing to support real time analytics for characterizing the local grid environment and react locally to perturbances. In addition, a prototype modular, upgradeable embedded communication interface for sensors will be developed to enable faster, simpler, secure integration of new sensors into a utility operational network.

In addition, through this topic PG&E intends to demonstrate new high velocity, high density sensor data streams combined with existing sensor data and associated analytics for real-time system protection not possible with current technology.

Lastly, PG&E intends to calibrate existing system models utilizing novel analytics methods and data streams as described herein.

In their EPIC 4 investment plan application, SCE also broadly proposes to explore new grid sensors and edge computing, and both SCE and SDG&E propose to pursue enhancements to their communications systems. These are broad areas of opportunity, and while each utility's projects and the technologies they pursue will be driven by their own distinct priorities and requirements, elements of each utility's efforts will be of applicability and interest to the other utilities. As such, PG&E will coordinate closely with SCE and SDG&E during project scoping to ensure efforts are complementary and not unnecessarily duplicative, and keep them appraised of any relevant results and learnings from its projects.

Expected Outcomes

This topic will provide the following outcomes:

- Demonstration of new sensors that address the various sensing needs as described in this topic, with focus on packaging sensors cost-effectively and re-using sensor data to support multiple use cases
- Demonstration of comprehensive communication systems that support battery-powered edge devices, workforce communication devices, high speed and high data rate producing sensors, leading-edge cybersecurity, coverage across all use cases including use cases unique to PG&E, and support for in-network and edge computing and distributed grid control
- Development of standards and prototypes to enable faster, simpler, more secure, integration of new sensors into a utility operational network
- Development of next generation meter technologies that enable grid edge analytics, earthquake analysis, phase detection, topology analysis, and grid edge area communication and coordination

- Informing PG&E's unified sensor, edge computing, cybersecurity, and communications strategy

Metrics and Performance Indicators

- Number of new sensor types deployed
- Throughput and latency of the communications system for the various and distinct PG&E use cases
- Percent increase of data available for analysis from sensors
- Percent accuracy improvement of information available to analysts
- Percent reduction in enterprise risk from the solutions enabled through this topic

Primary Users and Beneficiaries

- **Customers** will benefit from more efficient and reliable operation of the electric system, with greater ability to support 100 percent clean energy, as well as improved protection from being able to better predict and diagnose equipment issues prior to failure.
- **IOUs** will be able to operate and maintain the grid more efficiently, reliably, and safely.
- **Technology developers and manufacturers** will benefit from demonstrations of their technology, incorporating feedback to improve their products, and subsequent adoption in the utility community.

Guiding Principles

- **Safety:** This topic will not only provide increased safety, but more effective and widespread analysis of electric grid equipment conditions and faster, more effective communications.
- **Reliability:** This topic will not only provide increased reliability, but more effective and widespread analysis of weather and electric grid equipment conditions.
- **Affordability:** This topic offers improvements in affordability by directly preventing costly unplanned outages and damage to utility assets.
- **Environmental Sustainability:** Environmental sustainability is enhanced by the reduction of environmental damage from the prevention of catastrophic grid-related

events such as wildfires, and through more efficient and carbon-free operation of the grid resulting in a lower environmental impact.

- **Equity:** Under-resourced communities are often the most vulnerable to and most impacted by outages and extreme weather events. Grid sensing, communication capabilities, and increased visibility into grid assets are important capabilities to prevent outages or mitigate weather-related disasters, potentially avoiding loss of healthcare, education, childcare, and work.

Background, Previous Research, and Technology Trends

IOUs are continuously looking for innovative sensors, communication systems, and analytical methods that can cost-effectively impact operations. National Labs, government agencies, universities, research organizations, and private industry are all developing these technologies that can be employed in the electric sector. However, they are at varying levels of readiness and often lack maturity that comes from demonstration in the harsh and sometimes extreme environment that PG&E operates in and often require specialized maintenance, tuning, and calibration that is not well suited for deployment at scale across large geographic areas. Finally, though PG&E has successfully demonstrated a range of new sensor types, there needs to be improvement in the coordination, management, and ability to synthesize and leverage the value of these and future sensor types.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	●
Generation	
Transmission	●
Distribution	●
Demand-Side Management	●

6. *Grid Scenario Planning*

Innovation Need

Existing long-term grid architecture work in progress at PG&E has highlighted four macro trends that are disrupting the traditional architecture of PG&E's grid:

1. Changing environmental and ecological conditions
2. Proliferation of new technologies with declining costs and enhanced capabilities
3. Evolution in how, when, and where end users consume electricity
4. Effective and sustained political will to decarbonize the state of California

The future is uncertain and yet our design principles are often based on what we've seen to date. With these macro trends, there is a need for a long-range whole system grid planning tool to inform decision-making on the 10 to 40-year time horizon. Current tools and processes either plan based upon past behavior and growth, cover only one part of the grid (e.g. generation, transmission, substation, or distribution), do not take into account sufficient up-to-date datasets to inform a comprehensive or accurate model, are too inflexible to answer the questions about the changes needed in the coming decades, or operate too slowly to be of sufficient help in efficient decision-making.

Description

This RD&D topic will support technology demonstration of a grid scenario planning engine to address this innovation need. The aim is to create a whole system grid simulator that analyzes a wide range of scenarios and potential future stressors to the grid, produces a proposed grid model, and distills grid design principles.

The topic would help answer the questions of what the grid should look like in 10 years and out to 40 years. The engine would take future-influencing dimensions as inputs and output what the optimal grid would look like to inform grid design principles and decision-making. These inputs could include usage behavior, major economic stressors, DER integration, EV adoption/building electrification, zonal electrification of the gas system, and climate change. This topic would explore how the model itself would even be built and what recurring datasets would need to be input to keep the model current as the grid topology changes. The model would need to be flexible, provide understandable and actionable outputs such as a grid model, advise on grid design principles, and guide on how to actualize the results. The topic would also explore how such a model's objectives could be configured, for instance, to maximally reduce wildfire risk, maximize energy equity, maximize decarbonization, optimize affordability, or minimize investments.

Included in this topic is the demonstration of the platform that would be needed to operate such a model, as current planning tools have very significant limitations that cannot scale to the enormity of the data (many tens of millions of distributed devices including but not limited to electric vehicles and inverter-based resources) and computations needed to perform whole grid scenario planning in a timely manner. PG&E would also explore whether the platform for this topic could be extended to support the many other short- and long-term studies that are performed, to bring them together out of their silos and to leverage common data and systems to improve the quality and efficiency of the studies and models.

PG&E has been and will continue to work alongside its fellow EPIC Administrators to coordinate on EPIC topics and projects to ensure non-duplication of work, to be able to collaborate on projects when possible, and to share project learnings. PG&E notes that SCE's End-to-end Advanced Simulations and Analytics topic in their EPIC 4 Investment Plan includes elements that may overlap with elements of this PG&E topic. While each utility will need to develop and leverage their own respective models to represent their own distinct systems, PG&E and SCE will continue to work together to ensure that the projects pursued through their respective topics are aligned and avoid unnecessary duplication.

Expected Outcomes

This topic will realize the original vision as proposed for the "Grid of the Future Scenario Engine" project approved, but not pursued, in PG&E's EPIC 3 plan, though with an expanded scope of modeling the whole system (distribution, substation, transmission, supply), with an expanded time horizon of up to 40 years, and with the required computing platform needed to perform such scenario planning, including providing answers to the following example questions:

- How many customers should be connected to a feeder, bank, substation, sub-transmission, or transmission system?
- What voltage levels should we operate at and where?
- How long should our feeders be?
- Where should we underground?
- Where should we conduct zonal electrification of the gas system?
- Where should we install grid-connected microgrids?
- Should the lines even go there?
- Where should we retire lines?
- Where should we re-route around HFTDs?
- Where should we build Remote Grids?
- Where should our lines follow roads vs. where should our lines traverse challenging terrain?

Metrics and Performance Indicators

- Cost-effectiveness of infrastructure investments
- Dollar cost savings of estimated additional avoided stranded assets

Primary Users and Beneficiaries

- **Customers** should benefit from lower rates as infrastructure investment can be more completely optimized and fewer assets might be stranded.
- **Energy regulators and planners**, including at the CPUC and CAISO, will benefit from the analytical approaches and model outputs used to communicate on long-term grid change planning activities.

Guiding Principles

- **Reliability:** The technologies developed under this topic will demonstrate how grid change can be planned out through multiple decades in support of a reliable system for all end users.
- **Affordability:** This topic aims to develop a comprehensive whole system grid scenario planning engine that will support affordability through the avoidance of unnecessary infrastructure investments and reduction of potential stranded assets.
- **Equity:** The modeling and simulation developed through this topic would enable PG&E to explore the best pathways to equitably transform the grid over the coming decades.
- **Environmental Sustainability:** By avoiding unnecessary infrastructure investments and reducing stranded assets there is a reduction of environmental impacts.

Background, Previous Research, and Technology Trends

Some research studies have been performed in this area. The first research, performed by Instituto de Investigación Tecnológica (IIT) Comillas in Spain, has modelled a European-style distribution network with higher secondary voltage and different network topologies than North America's grid. The second research performed by National Renewable Energy Laboratory (NREL) utilizes the findings of IIT Comillas' work and implements it on North American-style grids. Both studies focus on possible future architecture of the distribution network, but not the transmission system or generation. There is also research funded through the U.S. Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E) with purely transmission system focus. However, there is not yet an engine developed to simultaneously model sub-transmission, transmission, and generation parts of the entire grid. The objective of this EPIC topic is to develop a holistic assessment of different possible scenarios of the entire future grid, including customers, primary and secondary distribution lines and components, sub-transmission, transmission, and generation.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	●
Generation	●
Transmission	●
Distribution	●
Demand-Side Management	

7. Advanced Drone Applications

Innovation Need

Currently, PG&E primarily uses manned aircraft and other manned vehicles for grid surveillance of approximately 17,000 miles of electrical transmission, distribution, and management assets. There are safety risks inherent in employing manned vehicles for field-related work, and manual monitoring creates opportunities for human error. PG&E has taken initial steps to incorporate some drone use cases into its operations, including the manual operation of drones within line-of-sight for the routine inspection of high-voltage lattice transmission towers. The continued incorporation of drones through wider and more advanced use cases has significant potential to improve the safety, effectiveness, and efficiency of system operations. Areas of opportunity include routine transmission, substation, distribution, and generation asset inspections, as well as ad hoc investigation of system issues, post-event patrols, vegetation monitoring, and potentially others.

Description

This topic will continue to advance PG&E’s drone applications by building upon the initial demonstration of automated and Beyond Visual Line-of-Sight (BVLOS) capabilities currently being demonstrated in PG&E’s EPIC 3 program. These capabilities will also be expanded to additional use cases beyond the narrow implementation in EPIC 3 for ad hoc investigation of alerts in the distribution and the automated inspection of lattice transmission towers and involve a wider range of onboard sensors.

Beyond exploring additional use cases, PG&E will also demonstrate better integration between vendor systems and PG&E's own work management systems and processes to enable more efficient workflow execution. PG&E will also explore the progression from limited scope and scale demonstration involving individual drones operating in isolation, to demonstration of smart networks of multiple drones, and explore the more holistic integration of manned and unmanned inspection processes. This topic will also demonstrate the application of larger drones for longer-range operations than have been applied by PG&E to date, which will involve more stringent Federal Aviation Administration (FAA) requirements and require even more robust drone systems.

Expected Outcomes

This topic will position PG&E to operationally deploy advanced drone systems across a range of PG&E use cases. As an expected outcome, PG&E intends to secure FAA approvals to allow for autonomous and BVLOS mission execution to unlock significant efficiency gains across a wide range of use cases, for multiple types and sizes of drones. As an additional outcome, PG&E will also progress from exploration of stand-alone drone systems to integrating vendors' systems into PG&E's own systems and processes. With more robust and advanced drone systems, FAA approvals to allow for broader and more flexible operations, and improved integration between vendor and PG&E systems, unmanned operations will increasingly become a viable and preferred alternative to conventional manned aerial and land-based vehicle operations within PG&E.

The precise, repeatable, and more frequent capture of asset and vegetation data across missions and over time that will be enabled by automated drone operations is also likely to significantly benefit machine learning, to improve asset health assessments, risk modeling work and targeted vegetation work.

Metrics and Performance Indicators

- Reduction in operating costs on an annual or per-operation basis
- Reduction in safety incidents on an annual basis
- Reduction in incomplete or insufficient mission data capture

- Reduction in end-to-end operation process time

Primary Users and Beneficiaries

- **IOUs** will employ and benefit from faster, more efficient, and more effective operations across a broad range of use cases.
- **Customers** will benefit from rate reductions associated with reduced operating costs that result from more efficient utility operations.
- **General Public** will benefit from improved safety due to reduced exposure to hazards associated with conventional manned aerial and land-based vehicle operations.

Guiding Principles

- **Safety:** Drone operations will improve safety by removing exposure to hazards associated with conventional manned aerial and land-based vehicle operations.
- **Reliability:** Drone operations have the potential to allow for faster investigation of emerging grid issues, as well as faster post-event patrols, to prevent outages and lessen the duration of outages.
- **Affordability:** Drone operations have the potential to yield significant operational cost reduction as compared to conventional manned aerial and land-based vehicle operations.
- **Environmental Sustainability:** The use of electric-powered drones will avoid the emissions associated with conventional manned aerial and land-based vehicle operations.
- **Equity:** New applications of drone systems can be deployed in disadvantaged or low-income communities at the wildland-urban interface, to reduce the inequitable wildfire risks faced by those communities, and reduce the inequitable impacts of air quality they face during wildfires

Background, Previous Research, and Technology Trends

The application of drone systems is still nascent within the utility industry. While more utilities are beginning to use drones for various aspects of their operations, most operate them manually and within visual line-of-sight. Few utilities have begun to employ automated, remote, and BVLOS drone applications, and in these cases, most operate within a limited range of use cases and narrowly-defined operational parameters. However, as both vendor solution offerings advance, and FAA regulation becomes more accommodating of advanced applications, there is increasing potential for PG&E to demonstrate and integrate advanced drone applications for the benefit of its operations and customers. Specifically, PG&E's EPIC 3.41 - *Drone Enablement and Operational Use* project is currently conducting a limited foray into demonstrating automated and BVLOS drone operations for very targeted use cases and operational parameters. PG&E intends to continue to work with drone system vendors and the FAA to advance its capabilities within EPIC 4.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	**Topic Applicable**
Grid Operations/Market Design	
Generation	●
Transmission	●
Distribution	●
Demand-Side Management	

8. Advanced Predictive Maintenance and Failure Cause Analysis

Innovation Need

In recent years, PG&E has begun to move to a more predictive and proactive mode of managing certain types of its assets. This change has involved improvements in inspection practices, as well as more data-driven monitoring that has involved both the deployment of additional sensor devices in the field and the development of purely analytical capabilities leveraging the extensive data PG&E already has at its disposal. Analytical capabilities have significant potential to provide actionable insights in managing assets and mitigating risks.

While administering its EPIC program, PG&E has built up a strong team of data scientists that have gained significant experience and expertise around grid and utility operations. In addition, PG&E is undergoing a major effort to improve data quality and access by establishing its central Foundry data management platform. These factors have contributed to the recent successful deployments of predictive maintenance tools, such as the tool developed through PG&E's EPIC 3.20 - *Data Analytics for Predictive Maintenance* project, for identifying issues with distribution transformers. However, there is an opportunity and need to continue developing analytical tools for the distribution system, where PG&E has been most focused to date, as well as for the transmission system and substations where there are perhaps even richer datasets and significant opportunity to develop powerful tools. Purely analytical tools have the potential to yield more cost-effective risk mitigation (or "risk-spend efficiency") as compared to other solutions that require the broad deployment of sensors and other hardware across the system.

Description

This topic will apply analytics to improve management and operation of assets and asset data for a range of asset types across distribution, transmission, and substation, as well as develop tools to predict deterioration, imminent failures, remaining useful life, high risk conditions, and the need for maintenance across these asset types. In line with these objectives, the models that are developed will also help to more accurately categorize asset failure mechanisms, improve data quality, and shed light on conditions in the system such as energy theft and unauthorized interconnections.

The overarching opportunity associated with this topic is to continue to derive as much value as possible out of the expansive set of data PG&E has at its disposal. Data sources applied to this topic will include, but not be limited to, SmartMeters, outage records, geographical information systems (GIS), weather data, supervisory control and data acquisition (SCADA), and other operational data sources. While building and demonstrating new analytical tools, it is expected that additional foundational work will need to be done to improve the quality, structure and accessibility of various underlying data elements. PG&E will also conduct extensive postmortem analysis of failed assets to better understand root causes of failures and inform the development of the predictive models.

The tools developed through this topic are expected to be applied in a decision horizon between days and months, which places them between the strategic planning timeframe and the real-time operational timeframe. For the distribution system, assets of potential focus include capacitors, reclosers, regulators, and underground conductors. For substations, the initial focus is likely to be on transformers and circuit breakers, before expanding to other assets. Assets of focus for the transmission system will include support structures (e.g., poles, towers, foundations), cross-arms, conductors, overhead ground wires, splices, jumper cables, anchors and guy wires, insulators, and various connector components.

Expected Outcomes

The demonstration projects conducted through this topic will result in predictive tools, connected to real-time operational data feeds, that are ready to transition into production development and use. Ongoing maintenance, and operational work processes and associated roles and responsibilities will be established for monitoring and triage of tool outputs, continuous improvement of the tools, as well as field investigation and corrective action. The following are additional expected outcomes:

- Significant intellectual property in the user interfaces and core algorithms developed, which PG&E will aim to apply to the maximum benefit of the EPIC program's customers. This may involve patenting, licensing, and monetization
- Improvements to the quality, structure and accessibility of the various underlying data elements that will be inputs to the tools that are developed
- Enhancements to PG&E's own internal data science expertise
- Enhancements to PG&E's central Foundry data platform

Metrics and Performance Indicators

- Number of asset types for which successful predictive models are developed

- Number and percent of true and false positive and negatives generated by the predictive models
- Number and percent of true positives predicted by the tools that were not otherwise identifiable by existing means
- Risk-Spend Efficiency estimates of tools if deployed at scale

Primary Users and Beneficiaries

- **IOUs** will leverage the tools developed through this topic for improved asset management of their own service areas.
- **Technology developers** may integrate the models developed through this topic into their own product offerings through licensing agreements with PG&E and make these capabilities available to a broader set of utilities outside of California.
- **Customers** will directly benefit from the reduction of risk and mitigation of outages that result from the tools developed through this topic. They may also benefit from any monetization by PG&E of the intellectual property developed, through a reduction in rates.

Guiding Principles

- **Safety:** Predictive maintenance tools prevent asset failures that could pose safety risks to utility employees and the general public. Preventing asset failures also reduces ignition risk.
- **Reliability:** Predictive maintenance tools prevent asset failures that cause outages for customers.
- **Affordability:** Predictive maintenance tools prevent failures and allow for preventative maintenance as opposed to more expensive unplanned asset repair and replacement, which reduces utility operating costs. Predictive maintenance models are also broadly applicable to other utilities, and there is an opportunity to license and monetize intellectual property and return a portion of the funds to customers.
- **Environmental Sustainability:** Predictive maintenance tools prevent asset failures that could ignite wildfires.

- **Equity:** Under-resourced communities are often the most vulnerable to and most impacted by outages and extreme weather events. Understanding past failure causes and proactively predicting maintenance of grid assets are important capabilities to prevent outages or mitigate weather-related disasters, avoiding potential loss of healthcare, education, childcare, and work.

Background, Previous Research, and Technology Trends

PG&E's EPIC 3 predictive maintenance projects made great strides in the state of the art but were limited in scope and performance by some challenges in data quality and availability. In general, the state of the art in predictive maintenance within the energy industry continues to improve though has consistently been limited by data quality challenges. PG&E will leverage its broader investments in data quality and process improvements, while leveraging the learnings of National Labs, utilities, and others to continue to push the state of the art forward. The existing frameworks for predictive maintenance and asset failure analytics will provide a path to production for any viable solutions developed.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	
Generation	
Transmission	●
Distribution	●
Demand-Side Management	

9. *Work Management*

Innovation Need

Many PG&E processes, and particularly complex processes and those that involve multiple stakeholder groups, can include multiple manual tasks, be inefficient, or have limited or outdated underlying technology solutions to operate them. With the advent of a multitude of new data sources related to these processes and PG&E's Foundry-based data integration and analytics platform that can leverage them, new analytical models could supplement or be a significant part of replacing them. These new tools would improve field employee situational awareness, project/worker safety, efficiency, and an improved customer experience.

Description

This topic would enable the demonstration of a range of technologies that could help improve various PG&E work processes, such as:

- Analytical models to optimize resource allocation and work staging. Examples of opportunities include:
  - Work management tool for wildfire risk areas. Every day, prior to work starting on a job, there are a myriad of mitigations that need to be taken based on location, weather, High Fire Threat District (HFTD) tier, and other operational and fire science-related data. This time-consuming mitigation calculation is performed manually and may be subject to error and interpretation. A tool that would replace this process would ideally be installed on the field workforce equipment and be able to automatically provide the needed mitigations quickly using the needed disparate sets of information sources.
  - Fully automated emergency field site construction tool. In order to release an emergency field site (e.g., a Base Camp, Micro Site, Staging Area, Materials Laydown Yard, or Landing Zone) to Construction, there is complex information exchange and decision making by numerous internal and external stakeholders. The tool would employ novel data and coordination processes and result in faster and more efficient time to completion of emergency site approval,

equipment mobilization, vendor services, and buildout thus increasing safety and lowering costs.

  - Field employee situational awareness tool to make the field worker aware of all relevant customer-, service-, and location-related information. Such a tool would use machine-learning techniques to determine the relevant information from the disparate data sources and provide an organized report suitable for rapid consumption by the field worker. The benefits are manifold, including improved customer service, safety, efficiency, and lower environmental impacts of field work.

- Augmented reality tool for shared situational awareness in standard and emergency conditions. One use case would be for providing a remote analyst with the ability to see the field worker's point of view in both standard operational and emergency conditions, to most quickly develop the most effective and safe plan of action. Another use case would be for remote operators or engineering SMEs to be able to provide overlaid diagrams and guide field technicians through a complicated procedure or repair, for enhanced safety and quality. This will also reduce the costs from, and interruption caused by, return jobs needed for re-work.
- Restoration time optimization tools that analyze the affected grid area for its topology and equipment, dynamic power flows, BTM DERs in the area, power factor, crew and resource availability, including prior work by SCE and SDG&E as referenced below.

PG&E notes that SCE's Safety and Work Methods Advancement topic in their EPIC 4 Investment Plan includes elements that, at a high level, overlap with elements of this topic. Work methods and work management is a broad area, and PG&E and SCE will continue to work together to ensure that projects that may be defined through their respective topics are aligned and avoid unnecessary duplication.

Expected Outcomes

- New work management tools that reduce risk, increase safety, improve efficiency and coordination, and reduce costs

Metrics and Performance Indicators

- Number of hours of employee time saved from the implementation of work management tools developed through this topic
- Number of hours of reduction in time to release emergency field sites to the construction group
- Number of hours saved in restoration time as a result of optimization tools developed through this topic

Primary Users and Beneficiaries

- **Customers** would benefit from an increase in safety as well as greater affordability through reduced utility costs.
- **IOUs** would benefit from more efficient, less error prone, safer work processes.

Guiding Principles

- **Safety:** Improved processes built on more complete data, and less prone to errors and interpretation, would lead to an increase in safety.
- **Reliability:** Improved efficiency of work would enable more scheduled work to be performed sooner, enhancing reliability.
- **Affordability:** Improvement to work management would result in lowered costs and greater affordability.
- **Environmental Sustainability:** More efficient work processes would lead to a reduction in environmental impact and a reduction in emissions from operations.

Background, Previous Research, and Technology Trends

PG&E's EPIC portfolio to date has not focused extensively on work management. Now that PG&E has established foundational data, analytics, and mobile workforce capabilities, PG&E can now leverage them to demonstrate the work management capabilities described in this topic. Regarding augmented reality, PG&E has observed the advancement of utility-specific augmented reality solutions, including through the EPRI Incubatenergy Labs program, which has explored application of augmented reality systems. PG&E is also aware of the augmented reality program SCE created to improve the way that linemen diagnose complex automation and protection equipment, determine if equipment is energized, and make repairs. PG&E is also aware that SDG&E, in its EPIC-3 Project 4, "Safety Training Simulators with Augmented Visualization", demonstrated and evaluated augmented reality applications for field-focused design, operations, and asset monitoring and management solutions in utility power systems, with a focused patrol simulator for the benefit of operator trainees, and a safety procedure aid for underground distribution field work. PG&E's emergency operations-focused use case for augmented reality is distinct from the SCE and SDG&E use cases. In general, augmented reality solutions for utilities are at an early stage and quite limited in capabilities. Technology options and innovative solution offerings are increasingly presenting an opportunity to make advancement through demonstrations in this area.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	**Topic Applicable**
Grid Operations/Market Design	●
Generation	
Transmission	●
Distribution	●
Demand-Side Management	

10. System Protection

Innovation Need

PG&E's electric system is changing rapidly, including from the significant increases in BTM and FTM DERs and renewable energy-based microgrids. PG&E's commitment to reliable, safe energy supply for its customers cannot be compromised, though the characteristics of these DERs and microgrids challenge our System Protection equipment, standards, and strategies.

Many unanswered questions remain in how to maintain and improve system protection as the grid equipment changes. There is also a need to further reduce wildfire risk from equipment ignitions and other environmental risks through innovations in system protection.

Description

This topic will demonstrate technologies needed for improved system protection in several areas:

- Improvement of system protection systems for faults generated by inverter-based resources including battery energy storage systems, as present protection systems rely on a current profile that is not provided in inverter-based microgrids. The current protection systems in these cases would not be fast enough to prevent an ignition. The demonstrations will focus on characterizing the faults common to inverter-based resources and microgrids, including fault types that are difficult to detect by existing protective relays, including by not limited to high impedance faults. The work would begin with inverter-based resource fault modeling seeking improvements to the modeling, validation of the models through laboratory testing, then application of the lessons learned and verification of the models and protection schemes through field installations.
- In companion with the above, demonstration of a new type of protective relay that uses "traveling waves" to detect faults instead of the traditional "phasor-based element" method. Traveling wave fault detection relays do not rely on elevated current levels and instead detect "disturbances". This would detect faults from batteries and inverter-based resources. Traveling wave relays could also be used to reduce wildfire risk since they can detect faults before they create damage (like broken conductors).
- New equipment that can add the needed modern telemetry (e.g. three phase reactive power) to legacy electro-mechanical substation relays without costly and service-disruptive relay replacements.
- Novel protection schemes that use machine learning applied to advanced line reclosers to detect more types of faults and to detect faults more quickly.

- Characterization of the effects on the primary neutral from three-phase opens during EPSS events.
- Novel capacitor bank controllers with precision three-phase multi-parameter telemetry are needed for the ADMS system, as well as for emerging improved substation and feeder protection analytics, for instance when combined with new substation-based telemetry as described above, the system could detect incorrect capacitor switching schedules, and partial capacitor fuse or switch failures. This analysis and protection can prevent ignitions due to capacitor failures and can improve the power quality performance of the grid.
- Adaption of transmission-level system protection algorithms to distribution system relays, in particular distance protection that analyzes voltage, frequency, current, and time all at once and applies various trip zones. Implementing distance protection in the distribution system would enable greater precision in limiting tripping to only directly impacted areas. This is particularly needed as the broad deployment of EPSS has limited fault currents and drastically limited time current coordination, therefore distance protection could allow for better coordination between protective devices. Differential protection is another transmission level protection algorithm that would allow better coordination and faster tripping in distribution. There are significant unsolved challenges that presently prevent the use of distance protection in distribution systems. This topic would investigate and demonstrate potential solutions to such issues, such as: enabling full load or generation output with the distance element settings when there are varying conductor sizes and presence of laterals; difficulty in detecting high impedance faults; coordination with Time Over Current (TOC) devices; and solutions for ground protection as it is not feasible to create ground distance protection on certain distribution installations due to wood pole construction, variable circuit topography, and grounding methods.
- New smart fuses that include telemetry to help improve EPSS operation.
- New fuses that would enable the removal of fuses that currently contain powerful greenhouse gases.

- Use of SmartMeter edge disturbance detection for fault isolation and system protection improvements.
- In coordination with PG&E's EPIC 4 Topic 5, "Grid Sensing and Communication", application of various communications technologies to improve tripping times and separating the electrical systems that cannot detect faults on their own.
- In coordination with PG&E's EPIC 4 Topic 18, "Pinpointing Fault Location", installation of fault location sensors and development of automatic fault location tools to determine the location of faults quickly and accurately. This will enhance the restoration time and improve reliability.

PG&E has been and will continue to work alongside EPIC Administrators CEC, SCE, and SDG&E to coordinate on EPIC topics and projects to ensure non-duplication of work, to be able to collaborate through joint projects when possible, and to share project learnings. PG&E notes that SCE's Adaptive Protection topic in their EPIC 4 Investment Plan includes elements that may overlap with elements of this topic. PG&E acknowledges that this is a broad area, and that PG&E and SCE will continue to work together to ensure that projects that may be pursued through their respective topics are aligned and avoid unnecessary duplication.

Expected Outcomes

The expected outcomes from this topic include:

- Demonstrations of new analytics, techniques, and equipment targeted at maintaining and improving system protection in the face of significant grid changes
- Informing the strategy for how these new system protection equipment, techniques, and systems could be added to, or perhaps replace, elements of existing system protection schemes
- Standardized approach to protections for microgrids formed utilizing inverter-based resources where fault current may be insufficient for conventional over current schemes

Metrics and Performance Indicators

- Number of nuisance faults prevented

- Number of reportable system protection-related events avoided
- Number of grid equipment failures prevented
- Amount of additional wildfire risk reduction as a result of protecting equipment that otherwise could have started a wildfire when faulting
- Amount of interconnection process time avoided for inverter-based resources specifically due to faster system protection analysis enabled from this work
- Improvement in System Average Interruption Duration Index (SAIDI) and Customer Average Interruption Duration Index (CAIDI)

Primary Users and Beneficiaries

- **Customers** will benefit from an improved protection system that better protects customer equipment and reduces wildfire risk with a minimal number of false fault detections.
- **IOUs** will benefit by maintaining or increasing reliability and protection capabilities as the grid transitions to high inverter-based resources.
- **Grid operators** will benefit from a more reliable and safe system that more clearly identifies faults and fault sources, including the types of faults from new types of resources that conventional protection systems weren't designed for.
- **Technology developers and manufacturers** will benefit from the feedback on product design and operation through the demonstrations, as well as input on potential new types of equipment, sensors, and monitors that would in the future provide higher levels of system protection.

Guiding Principles

- **Safety:** A primary benefit of the topic is increased safety by properly detecting and acting on faults of all kinds, including the new types of fault conditions not readily detectable by traditional protection equipment. This increased protection can also reduce wildfire risk.
- **Reliability:** Reliability will increase when faults and power quality issues are correctly identified and dealt with more quickly and precisely.

- **Affordability:** As faults and wildfires cause expensive damage and destruction, a grid that better protects itself and customers' equipment from these events is more affordable.
- **Environmental Sustainability:** There is a benefit to the environment from prevention of wildfires, reduction of grid equipment that is damaged and requires replacement, and potentially a reduction of use of a potent greenhouse gas.
- **Equity:** As many vulnerable, under-resourced communities are in high fire threat areas, they would benefit from additional wildfire risk reduction.

Background, Previous Research, and Technology Trends

System protection is the cornerstone of safe and reliable operation of the electric grid, and consequently has steadily become more complete, but the introduction of inverter-based resources has complicated protection schemes and subtly slowed the connection processes for microgrids, as each installation became a custom protection scheme.

Inverter-based resources have also made detecting faults more challenging since present protection practices are based on equipment that relies on traditional generation sources. Traveling-wave and incremental-quantity-based relays are state-of-the-art technologies that do not possess these limitations, therefore helping to potentially overcome some of the new challenges associated with microgrid protection.

With the advancement of sensor and control systems, a more sophisticated approach to system protection can be enacted. System protection can be smarter and more localized with faster response and even become learning-based.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	●
Generation	

Transmission	●
Distribution	●
Demand-Side Management	

CHAPTER 3: Increase the Value Proposition of Distributed Energy Resources to Customers and the Grid

Distributed energy resources (DERs) are key to achieving California's clean energy goals. DERs have the potential to deliver significant benefits to grid operators and electricity users in a high-renewable, highly electrified future. These potential benefits include load flexibility, peak demand reductions, reducing or deferring grid upgrades and associated costs, and improving climate resiliency, grid reliability, and providing compensation to DER owners. There are, however, operational challenges to integrating and maximizing the value of DERs on the grid. The topics in this strategic objective are grouped into the Distributed Energy Resources and Load Flexibility initiative, and the Transportation Electrification initiative. The topics will help develop the technologies and operational capabilities that will improve our understanding of how to maximize the value proposition of distributed energy resources to customers and the grid.

Distributed Energy Resource Integration and Load Flexibility Initiative

The ability to integrate an increasing number of DERs into the grid, and the ability to understand, direct, optimize, and compensate for power flows on a high renewables grid is central to meeting the State's clean energy goals. The following topics will help PG&E achieve these goals.

11. Interconnection Enablement

Innovation Need

Large, localized loads and generation, when not synchronized, can cause reliability challenges. In the face of accelerating load growth from building and transportation electrification, PG&E has limited available distribution service capacity, long lead times for, or external impediments to, building new capacity, and limited capital available for capacity investments. As a result, PG&E is often either unable to interconnect new customer loads or generation or must set static constraints on their operation for them to be interconnected. Rapidly increasing EV charging loads, including from commercial EV fleets, would require significant grid infrastructure upgrades at a rate that would not be possible to accommodate using only currently available solutions for accommodating new service connections. Similarly, PG&E has limited hosting capacity for new generation. New generation resources often face costly and long lead time capacity upgrades that may be able to be mitigated with novel and advanced solutions. In short, there is an urgent need and opportunity to explore a wider range of solutions for eliminating barriers to timely, smarter, more flexible customer service connection and generation interconnection.

Description

This topic will demonstrate a range of solutions for enabling the interconnection of distributed energy resources and new service connections of new and growing residential and commercial customers' loads and DERs, beyond conventional upgrades to conductors and transformers or the establishment of static constraints as a prerequisite for interconnection.

This topic will explore the enhancement of PG&E's Distributed Energy Resource Management System (DERMS) capabilities to provide greater visibility into dynamic grid capacity and convey signals or commands to participating DERs as an alternative to static constraints. This could allow for all customers to be treated as flexible load and/or generation, and not just the customers that would have otherwise triggered the need for upgrades. Enabling technologies at the meter or on the customer side such as smart inverters, smart panels, load control devices, load limiters and smart appliances could be included in the demonstrations. The demonstration of dynamic load and generation management will potentially also inform updates to standards and the implementation of new customer programs and interconnection offerings.

This topic may also further explore the establishment of dispatchable storage, (either front-of-the-meter (FTM) or behind-the-meter (BTM), as a short or long-term alternative to distribution upgrades. One potential use case for demonstration would be to partner with an EV charging infrastructure vendor on the use of stationary or portable battery storage to avoid a spike in grid demand at a small to medium size charging site. Other areas of exploration include the use of price signals or peer-to-peer transactional markets to relieve capacity constraints on the distribution system.

Lastly, this topic will also explore streamlined approaches for ensuring cybersecurity of new DERs and other dynamic load management equipment that are interconnected to the grid. For example, this topic may demonstrate the use of blockchain technology as a more distributed and cyber-secure approach to integration with 3rd party-owned equipment.

Expected Outcomes

The following are the expected outcomes of the demonstrations conducted through this topic:

- Faster and less expensive connection of customer loads and DERs
- Demonstration of dispatchable FTM storage as an alternative or bridge to conventional upgrades at one or more sites
- Enhancements to PG&E's DERMS platform to allow for communication of dynamic constraints to customers' DERs and dynamic load management equipment to enable automated load management
- Updates to standards and the implementation of new customer programs for participation in automated load management and flexible interconnection
- Implementation of new solutions that provide greater visibility into dynamic grid capacity
- Evaluation of local control technologies and requirements to respond to grid signals
- Advisory plan for cybersecurity implementation of the DERs and dynamic load management equipment

Metrics and Performance Indicators

- Reduction in time to connect new load and generation on capacity-constrained feeders
- Number of customers participating in flexible service connection and flexible interconnection arrangements through alternate solutions, that would have otherwise required conventional system upgrades
- Avoided costs associated with alternate interconnection solutions

- Increased capacity utilization of grid (rather than planning and building for worst case scenario)
- Faster, more flexible and potentially more cost-effective service connection and generation interconnection processes
- Deferred or avoided system upgrades driven by service requests (i.e. electrification) and new generation interconnection requests

Primary Users and Beneficiaries

- **Customers** will benefit from decreased costs and timelines for the interconnection of their DERs
- **IOUs** will benefit from reduced operating costs and improved customer satisfaction from less costly and faster DER interconnection processes
- **Under-resourced communities** will benefit from reduced barriers to access to clean DERs within their communities
- **Technology developers and manufacturers** will benefit from learnings gained through technology demonstrations that will help them enhance their product offerings

Guiding Principles

- **Safety:** Visibility into dynamic grid loading can avoid safety hazards in hometowns caused by overloaded equipment.
- **Affordability:** The alternatives to conventional distribution transformer and conductor upgrades demonstrated in this project will not only reduce interconnection timelines but will also likely reduce total costs.
- **Environmental Sustainability:** Removing barriers to interconnection enables the proliferation of clean DERs on the grid.
- **Equity:** While the solutions demonstrated through this topic will be broadly applicable to all customers, PG&E will explore opportunities to conduct demonstrations in Disadvantaged and Low-Income Communities specifically, to reduce costs and barriers to clean DER integration in those communities.

Background, Previous Research, and Technology Trends

While exploration of procuring DERs to defer planned capacity upgrades as “non wires alternatives” has been underway in California and elsewhere, the use of DER controls to manage operational (i.e. real-time) distribution grid capacity constraints is still in its infancy with limited RD&D projects having been executed across the country to explore the topic. This effort would build upon past industry and PG&E work in this area including PG&E’s EPIC 2.02 - *Distributed Energy Resource Management System* and EPIC 3.03 - *Distributed Energy Resource Management System (DERMS) and Advanced Distribution Management System (ADMS) Advanced Functionality* projects, to further develop and validate the key technologies, integrations and processes required to operationalize these critical use cases at scale. This topic will also leverage previous efforts to develop grid responsive load and generation controllers that can reliably respond to utility signals and commands. Additionally, the topic will continue to facilitate further development of key standards for DER capabilities and communications protocols that continue to evolve and mature as the industry strives toward more plug-and-play integration across the DER ecosystem.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	●
Generation	●
Transmission	
Distribution	●
Demand-Side Management	●

12. *Advanced Distribution Power Flow Management*

Innovation Need

As DERs along with transportation and building electrification loads continue to grow, power flow on the distribution system and secondary side of service transformers is increasingly complex. There is an urgent need for accurate and timely visibility into power flow, that, among other things, will be used to maximize the value of DERs for customers and for the utility. There is also a need for deeper and wider coordination, optimization, and facilitation of compensation to the DER owners for cooperating to provide grid services.

Several constraints additionally drive the need for this innovation. They include limited distribution service and substation capacity, many limitations impeding complete distribution or substation upgrades, and that if an upgrade is required it may take longer to complete the upgrade than is required to keep up with the DER supply and electrification growth needs.

Description

This topic will demonstrate a range of capabilities to meet the innovation need:

- Correctly inferring the topology of the grid with higher fidelity through new analytical methods that combine with existing SmartMeter data, SCADA, GIS, other available and novel grid sensors, next generation meters, and other data sets. This builds upon prior work through EPIC 2.14 - *Automatically Map Phasing Information*, and subsequent analytical work; the result will be an accurate and up-to-date topology that will be used to first identify transformers mapped in the wrong location, laterals in abnormal switching states, un-documented jumpers, and other errors. This first will be used to improve the safety, efficiency, and reliability of the grid. Secondly, the results will be used as the accurate foundation that other parts of this topic will build upon to maximize the value of DERs.
- Accurate visibility of power flows in the distribution system, on secondaries, and in microgrids through a combination of existing telemetry-enabled grid equipment, grid sensors, SCADA, as well as new sensors. The visibility tool would also be able to identify

instances of PV overgeneration and unpermitted PV generation to inform safety-oriented operational practices. The tool would also provide worker safety benefits through real-time notification of unexpected power flows in the area where workers are known to be operating.

- Automated tool that can identify grid constraints, overloaded equipment, and reverse power flows.
- Expansion of the foundational DERMS work performed through PG&E's EPIC 3.03 - *Distributed Energy Resource Management System (DERMS) and Advanced Distribution Management System (ADMS) Advanced Functionality* project, to progress from DER communication to DER control.
- Operational flexibility capability is the ability of a grid operator to make grid topology changes as operational conditions change, such as for maintenance, upgrades, equipment failures, or for emergency situations. DERs pose an additional worker safety, protection, and management challenge as grid topology changes are made. Additional DER-related operational flexibility capabilities need to be developed, demonstrated, and operationalized.
- An automated tool to identify areas where grid upgrades could be deferred if customers in the area added sufficient amounts of grid-supporting EVs, energy storage, PV, and load control devices. An analysis of customer behavior to determine viability would be included in this tool project.
- Building upon the foundational work of EPIC 2.03 - *Smart Inverters* and low-cost telemetry aspects of the EPIC 3.11 - *Distributed Energy Resource Management System (DERMS) and Advanced Distribution Management System (ADMS) Advanced Functionality* projects, PG&E continued validation of the advanced features of IEEE 2030.5 Smart Energy Profile Application Protocol including, for instance, dispatching and curtailing. This validation would include testing with many different smart inverters in a high DER environment, to assess the amount of BTM DER curtailment that is occurring to determine what could be changed to reduce the amount of BTM DER curtailment or other undesirable interaction between the smart inverters. Included in this work would

be a demonstration of the emergent use cases from the Smart Inverter Operationalization Working Group (SIOWG).

- Capabilities to load share during overload situations by novel technologies that can direct power flows from an underutilized grid area to the overloaded grid area.
- Automated operational tool that would coordinate and optimize dispatching of all available FTM DERs as well as BTM DERs including EVs and flexible loads. Additionally, the tool would provide hourly and day ahead distribution forecasts for a feeder. This topic would also inform PG&E on how such a tool would progress toward operationalization in a Distribution System Operator (DSO) model.
- Development and demonstration of uses cases for DER export (including grid support and market participation), along with corresponding communication and control schemes as well as customer preference and compensation including micro-payment models. Use cases include normal operational conditions, under operational flexibility grid topology changes, and in emergency and overload situations.

Expected Outcomes

The expected outcomes from this topic include:

- An accurate, highly-detailed grid topology tool
- Accurate, real-time power flow visibility
- Expansion of DERMS to include DER control
- Accommodation for operational flexibility needs
- Automated tool that determines grid upgrade deferral opportunities
- Deeper understanding of smart inverter capabilities, integration, curtailment, and high-DER inverter interactions
- Grid-supportive DER optimization tool with a customer compensation demonstration
- Wildfire risk reduction due to additional protection from equipment overloads, degradation, and damage as well as identification of switching or configuration errors that could cause ignitions

Metrics and Performance Indicators

- Accuracy of topology analysis created versus actual
- Ability to detect switching or configuration errors
- Accuracy of distribution power flow measurements versus actual
- Ability to identify grid constraints, overloaded equipment, and reverse power flows
- Ability to provide hourly and day ahead distribution forecasts for a feeder
- Ability to compensate DER owners for providing grid support
- Number of DER owners that participate in and receive compensation from the demonstrations

Primary Users and Beneficiaries

- **Customers** will benefit from the reliability, safety, affordability, and environmental sustainability improvements realizable through this topic, as well as from potential compensation for grid support.
- **IOUs** will benefit from grid support of participating DERs as well as the ability to meet DER and electrification load growth without capital-intensive grid capacity upgrade projects.
- **Grid operators** will benefit from new tools that improve the reliability and safety of the grid.
- **Technology developers and manufacturers** will benefit from having their emerging products evaluated and demonstrated and would be able to improve their products through demonstration experience and utility feedback.

Guiding Principles

- **Safety:** Power flow visibility enables additional grid protection that can prevent ignitions as well as improve worker safety.
- **Reliability:** A grid that is protected from power flows that are beyond operational limits will be more reliable. Enhanced reliability will also come from optimizing the participation of all FTM and BTM DERs as well as load management in support of grid stability.

- **Affordability:** Being able to defer capital intensive grid upgrades through optimization of FTM and BTM resources will lead to greater affordability. Affordability is also enhanced through compensation to DER owners for participation in grid support.
- **Environmental Sustainability:** Sustainability is served by increasing the amount of renewable energy that can be integrated into grid operations.

Background, Previous Research, and Technology Trends

The National Renewable Energy Laboratory (NREL) has recently developed a real-time optimal power flow-based distribution resource management system. The capabilities include the management of a distribution system with a high penetration of DERs including by leveraging the data from advanced metering devices and building management systems. NREL has used grid emulators to test the platform, though as the platform has not yet been tested in a realistic grid-installed scenario or even with actual grid models and data, its real-world applicability and behavior is unproven. A more advanced platform could be developed and tested properly in a real-world grid environment through this topic. This topic area would also build upon the DER head-end communication and control system developed with EPIC 3.03 - *Distributed Energy Resource Management System (DERMS) and Advanced Distribution Management System (ADMS) Advanced Functionality* project. That project enabled low-cost sharing of DER telemetry data, and PG&E will now leverage this platform to build out the control side allowing for communication of dynamic constraints to customers' DERs and dynamic load management equipment to enable automated load management capability.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	**Topic Applicable**
Grid Operations/Market Design	●
Generation	
Transmission	

Distribution	●
Demand-Side Management	●

Transportation Electrification Initiative

As California pursues ambitious targets to transition the transportation sector to zero-emission technologies, PG&E needs to improve its ability to support reliable, compatible, affordable, coordinated charging solutions located where and when needed. PG&E has also committed to deploying an unprecedented amount of electric vehicle second-life battery energy storage in a short number of years. The two topics in this Transportation Electrification initiative support these targets and commitments.

PG&E recognizes no duplicative or conflicting activities between D. 22-08-024[20] and D. 22-11-040[21] and ~~other transportation electrification (TE) projects under EPIC 4~~the topics described below that comprise this Transportation Electrification (TE) initiative . PG&E will pursue opportunities to share EPIC project outcomes and learnings with teams working on activities related to these two decisions as the outcomes and learnings from EPIC may ultimately serve to be complementary to the objectives and directives in D. 22-08-024 and D. 22-11-040. With regard to D. 22-08-024, the objectives and areas of study within the ~~TE~~TE EPIC projects do not seek to develop protocols that would either conflict with or change the applicability of the protocols established in D. 22-08-024. While the EV infrastructure rebate programs established in D. 22-11-040 have not yet been designed and implemented, PG&E does not anticipate overlapping or conflicting activities with the TE EPIC projects as they ~~do~~will not seek to design and implement new EV infrastructure rebate programs.

[20] D. 22-08-024 Decision Adopting Plug-In EV Submetering Protocol and EVSE Communication Protocols

[21] D. 22-11-040 Decision On Transportation Electrification Policy And Investment

13. *Electric Vehicle Charging and Integration Enablement*

Innovation Need

Electric Vehicles (EV), from fleets of medium and heavy trucks to millions of light duty vehicles, rely on reliable, compatible, affordable, coordinated charging solutions located where and when needed. Substantial innovation, demonstration, and coordination will be required to scale EV adoption in support of California's climate sustainability goals. Through this topic, PG&E will leverage prior CEC research and work cooperatively with stakeholders to understand and address the challenges that an evolving EV charging and integration landscape presents to the grid.

Description

PG&E will conduct demonstrations in the following areas:

- Improvement of the EV charging experience for all customer segments and charging profiles. This includes exploration and demonstration of:
    - Bidirectional fast DC and AC charging systems
    - Fixed or in-motion wireless charging technology
    - Novel battery swapping systems
    - Powering EV charging locations though movable energy storage solutions
    - EV submetering systems and equipment
- Incentivized and managed charging of EVs to minimize grid congestion and align with availability of renewable resources.
- Interoperability and coordination of customers to use vehicle-to-anything (V2X) integration for customer resiliency for planned and unplanned grid outages, in support of the electric grid, or for other potentially beneficial use cases. This demonstration would include creation of an EV charging and V2X technology laboratory for the purposes of this topic as well as for the purpose of being an available industry resource to test interoperability and help speed the advancement of EV technology.
- Analysis to understand of the round-trip efficiency of EV charging and V2X to inform grid planning.

- New and novel EV detection methods to:
    - Enable the Advanced Distribution Management System (ADMS) and Distributed Energy Resources Management System (DERMS) to coordinate behind-the-meter (BTM) resources, balance load and supply, and potentially avoid or defer grid upgrades
    - Better predict transformer overload and prevent service interruptions and ignition risk
    - More effectively target customers for EV related programs or to encourage off-peak charging
- Analysis of electrified PG&E service vehicles as mobile, plug-in power facilities in times of emergency or for critical loads during grid outages or in times of grid constraints.
- Exploration of effective pathways to best support vulnerable, underserved, ~~and~~ disadvantaged and low-income communities with appropriate EV charging solutions.
- Exploring the integration of EV and Electric Vehicle Service Equipment (EVSE) submeter data with PG&E Advanced Metering Infrastructure (AMI) data, including:
    - Potential to transmit smart meter data over EVSE wireless connections in real-time
    - Analysis of submetering data and EV and EVSE data to evaluate consistency of data and to determine impact of EV charging (and discharging) on grid in relation to house loads
    - Real-time assessment of loads on distribution transformers using data described above

Expected Outcomes

- Improved communication, standardization, and interoperability amongst charging infrastructure and grid infrastructure
- New charging technology solutions
- Improved grid planning tools
- Improved protection of grid infrastructure

Metrics and Performance Indicators

- Number of EVSEs and EVs tested for interoperability
- Number of kWh of EV charging load shifted through incentivized, managed charging
- Ability to accurately detect EV charging loads
- Ability to utilize alternative network connections for transmission of smart meter data and the subsequent ability to protect distribution assets from overloads due to EV charging

Primary Users and Beneficiaries

- **Ratepayers** will benefit from being able to charge their EVs when and where they want sooner and with greater ease.
- **Grid operators** will benefit from this topic by using the contribution of grid connected EVs to ensure reliability, safety, and stability.
- **Under-resourced communities** will benefit from lower local emissions and improved grid reliability as well as increased resiliency through V2X-capable EVs.
- **Technology developers and manufacturers** will benefit by testing and offering new equipment and services to assist in the rapid deployment of EVs.

Guiding Principles

- **Safety:** A grid that integrates bidirectional EVs where and when they are needed, without overload or ignitions, delivers on safety.
- **Reliability:** Reliability will be enhanced by grid supportive EVs.
- **Affordability:** By combining bidirectional EVs and emerging grid management systems, grid upgrades can be avoided, leading to increased affordability.
- **Environmental Sustainability:** Transportation electrification reduces internal combustion engine emissions, improves air quality throughout PG&E's territory, and contributes to company and state-wide goals for environmental sustainability.
- **Equity:** Disadvantaged and low-income communities will be targeted for demonstration to help with transportation electrification and attendant benefits from it in those communities. Since DACs might not have the high penetration of EVs that would be

needed as the basis to conduct the demonstrations, PG&E will look for opportunities to align EPIC funds with resources from other customer programs and upcoming Federal funding opportunities to provide communities with the EVs needed as the basis for the demonstrations. As part of local demonstrations, PG&E will ~~seek~~explore partnership~~s~~ opportunities with community-based organizations to better understand a community's barriers to accessing EVs, prompt recommendations for EV charging at single-family and multi-family homes, and facilitate two-way education between PG&E and the specific community.

Background, Previous Research, and Technology Trends

Small pilots have already been completed that confirm EVs can contribute to market mechanisms which support grid services. However, many other opportunities have not been addressed:

- Standardization and interoperability amongst charging infrastructure would both create greater customer engagement as well as speed EV adoption.
- Innovative charging infrastructure technology solutions such as buffered and wireless charging, as well as battery swapping pose benefits to EV operators and the grid alike.
- Integration of EV data and capabilities into grid planning tools would help identify and visualize short-, medium-, and long-term EV adoption trends that can also be shared publicly with charging station developers which also consider environmental and equity goals.
- Planning tools which enable large-scale commercial fleet operators to quickly add multiple megawatts of load at various locations, especially along major transportation corridors.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable

Grid Operations/Market Design	●
Generation	●
Transmission	
Distribution	●
Demand-Side Management	●

14. Electric Vehicle Battery Re-Use for Stationary Energy Storage

Innovation Need

PG&E has set a goal to deploy at least 500 MWh of second-life electric vehicle (EV) batteries for grid-connected energy storage as part of its 2030 Climate Goals[22], providing a low-cost flexible resource to PG&E and enabling customers to maximize the value of their EVs by lowering the total cost of ownership through an end-of-life value pathway. Batteries retired from EV use are available today and as California moves to 100 percent new sales of Zero Emissions Vehicles (ZEV) by 2035, every year an increasing amount of EV batteries will be retired and become candidates for re-use. Although there has been prior research by the CEC including limited demonstration of smaller-scale second-life batteries in California, PG&E needs to learn how to economically procure, interconnect, and safely operate larger grid-scale second-life battery storage system to meet its 2030 Climate Goals.

Description

PG&E seeks to conduct demonstration and analysis to identify key utility requirements for the efficient and effective deployment of second-life batteries as grid scale resources. Through the demonstrations PG&E will:

22. Pacific Gas and Electric Company. 2022. PG&E Climate Strategy Report. https://www.pge.com/pge_global/common/pdfs/about-pge/environment/what-we-are-doing/pge-climate-goals/PGE-Climate-Strategy-Report.pdf.

- Generate insights for the most economical methods of siting, deploying, and safely operating grid scale second-life battery storage systems
- Explore use cases for second-life projects (e.g. wholesale energy, peak load, distribution support)

PG&E has already begun to coordinate with the CEC on this topic to ensure that we leverage all of the prior work of the CEC in this area to inform our demonstrations and will explore the possibility of pursuing a joint effort with the CEC, in which the CEC funds a vendor to develop and configure a demonstration-ready grid scale system, and PG&E funds the siting and necessary “make-ready” integration work. PG&E will also collaborate with SCE and SDG&E on second-life battery energy storage system demonstrations to ensure information sharing and non-duplication of work.

Expected Outcomes

Through one or more demonstration projects, PG&E seeks to identify the path to production needed to meet its 2030 Climate Goal of repurposing at least 500 MWh of second-life batteries for grid-connected energy storage. This may include:

- Evaluation of the acquisition, deployment and operational processes for second-life battery energy storage systems
- Analysis of second-life battery energy storage ownership and contracting models
- Identification of the operational roles and responsibilities and potential needed changes to standards and work methods to deploy at scale
- Analysis of potential resiliency and reliability improvements for the customer and the grid brought by second-life battery energy storage
- Understanding the customer journey for end-of-life EV battery monetization

Metrics and Performance Indicators

- MWhs of second-life batteries used for grid-connected energy storage
- Percent availability (uptime) of second-life battery energy storage

Primary Users and Beneficiaries

- **Customers** with an EV battery at the end of its useful service life benefit from being able to sell the EV battery to the second-life grid-connected energy storage market, avoiding disposal costs. PG&E customers would also benefit from lower energy bills as grid-connected energy storage built with second-life batteries may be less expensive than that built with new batteries.
- **IOUs** will benefit from knowing how to safely and cost-effectively interconnect and operate second-life battery energy storage at grid scale.
- **Grid operators** will benefit from the additional reliability and resiliency benefits of this second-life battery-powered grid-connected energy storage.
- **Regulators and planners** will benefit by being informed on potential policy needed to maximize value and reliability of second-life batteries, including but not limited to additional safety standards that may be needed.
- **Technology developers and manufacturers** will have greater certainty in the value of second-life energy storage and the commercialization and scaling needed to support the rapidly growing second-life battery market. Our feedback, in particular for safety standards and grid interconnection procedures, will help technology developers and manufacturers mature and improve their offerings.

Guiding Principles

- **Reliability:** Grid-connected energy storage enabled through second-life batteries will improve reliability and resilience on the electric grid.
- **Affordability:** As part of a circular economy, there will be valuable second-life uses for EV batteries, lowering total cost of ownership of the EV and the cost of grid-connected energy storage.
- **Environmental Sustainability:** Diverting EV batteries for second-life re-use reduces the environmental effects from the mining and processing of battery materials as well as disposal.

- **Equity:** PG&E will explore the viability of deploying second-life battery energy storage systems in locations that benefit disadvantaged and low-income communities specifically, as well as opportunities for the second-life battery energy storage system vendors to coordinate the procurement of the batteries needed for the demonstrations from these same communities. As part of local demonstrations, PG&E will facilitate knowledge sharing between PG&E and local community-based organizations to further understand how second-life battery energy storage system can improve local energy resilience.

Background, Previous Research, and Technology Trends

The CEC currently has four projects (funded thorough GFO 19-310) that are improving battery second life technologies and demonstrating performance in behind-the-meter (BTM) applications to build market confidence. Those projects are:

- Low-Cost and Easy-to-Integrate Second-Life Battery Heterogeneous Unifying Battery (HUB)[23]
- Reuse of Electric Vehicle Batteries for Solar Energy Storage[24]
- Cost Effective Integration of Second-Life EV Batteries with Solar PV Systems for Commercial Buildings[25]
- Enabling EV Battery Circular Economy[26]

23. https://www.energizeinnovation.fund/projects/low-cost-and-easy-integrate-second-life-battery-hub
24. https://www.energizeinnovation.fund/projects/reuse-electric-vehicle-batteries-solar-energy-storage
25. https://www.energizeinnovation.fund/projects/cost-effective-integration-second-life-ev-batteries-solar-pv-systems-commercial-buildings
26. https://www.energizeinnovation.fund/projects/enabling-ev-battery-circular-economy

These CEC projects each include: 1) controlled laboratory testing and accelerated aging of various used EV batteries to better characterize and predict degradation and remaining useful life during second use, and 2) behind-the-meter demonstrations of second-life battery systems to integrate local solar PV generation and provide backup power during outages with small to medium commercial customers. These projects are generally deploying systems with several hundred kWh capacity, and there may be opportunities to advance these technologies to larger utility-scale applications.

Barriers faced by companies commercializing solutions include the proper assessment of state of health and safety profile of re-used batteries as well as the monitoring and analysis of degradation values of batteries once placed into second-life use. These factors and others directly impact the cost-effectiveness, supply chain formation, availability, durability, and safety of second-life battery energy storage system deployment in front-of-the-meter (FTM) applications at grid scale. The learning from the CEC's present BTM projects will be leveraged for the grid scale FTM demonstrations that PG&E aims to conduct for this topic, preferably in collaboration with the CEC.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	
Generation	
Transmission	●
Distribution	●
Demand-Side Management	●

CHAPTER 4: Inform California's Transition to an Equitable, Zero-Carbon Energy System That Is Climate-Resilient and Meets Environmental Goals

As California transitions to an equitable, zero-carbon energy system, PG&E must ensure that the grid is resilient and reliable in the face of climate change, and support California's and its own environmental goals. The EPIC program can be instrumental to providing the sustained investment needed for technology development and demonstration to address the significant challenges ahead to arrive at this future. This Strategic Objective contains the single Climate and Environment initiative.

Climate and Environment Initiative

PG&E's nine topics in this initiative are wide-ranging and include new modeling, new and emerging equipment, new inspection and analysis methods, new operational processes, and new ways of interacting with customers.

15. Preventing Faults from Causing Ignitions

Innovation Need

In recent years, climate change has caused a significant increase in wildfire risk within California and across the western United States. In response, and as described in its annual Wildfire Mitigation Plans, PG&E has employed extensive efforts to enhance its understanding of dynamic risk and the health of its assets, and to reduce the occurrences of asset failures and faults in high fire risk areas. While PG&E continues to work to minimize the occurrences of faults, it will not be able to completely prevent faults from occurring and has also taken steps to reduce the risk of faults causing ignitions and wildfires.

A primary method of reducing the risk of faults causing ignitions and wildfires is through rapid de-energization when a fault or potential problem is detected. For example, PG&E is broadly modifying the settings and increasing the sensitivity of its existing protective devices through its

Enhanced Powerline Safety Settings (EPSS) initiative, to automatically de-energize powerlines when potential problems are detected. Through the EPIC 3.15 - *Proactive Wires Down Mitigation* project, PG&E is also demonstrating novel substation-based Rapid Earth Fault Current Limiter (REFCL) technology that has the potential to rapidly reduce current to less than an amp for specific types of faults on distribution circuits. While these are examples of viable rapid de-energization capabilities, there are still opportunities to enhance overall capabilities to reduce false positive and negatives, address specific types of faults that pose challenges for current solutions, increase the speed of de-energization, and reduce overall solution deployment costs. Beyond rapid de-energization capabilities, there are also potentially other opportunities for innovation to prevent faults from causing ignitions. These include novel technological methods of removing or modifying vegetation fuel from under our rights of way, new materials for coatings to self-extinguish arcs, as well as alternative conductor materials.

Description

Through this topic, PG&E will demonstrate a wide range of technologies for preventing faults from causing ignitions. A major area of focus will be on capabilities that can either rapidly de-energize or drastically reduce current just after faults have occurred, as well as sensing technologies with edge computing that can de-energize lines just before external objects make contact with our assets and cause faults. PG&E will explore de-energization technologies that are capable of detecting and responding to high-impedance faults as well as lower-voltage faults in the secondary system, which have historically been challenging for existing solutions to address. Examples of rapid de-energization technologies include accelerometers mounted to powerlines that can detect a falling line before it hits the ground, syncrophasor-based fault detection, and real-time edge processing of Light Detection and Ranging (LiDAR) sensors that can anticipate contact with external objects and de-energize just before contact and resulting faults occur.

Beyond rapid de-energization solutions, this topic will also demonstrate solutions for efficiently and potentially autonomously removing vegetation on the ground along PG&E rights of way, new technologies for securing conductors, dynamically adjusting protection parameters in real time based upon conditions, new material coatings for assets to self-extinguish arcs, or even fundamentally new high temperature superconducting conductors that do not pose the same risk of ignition in wire down events.

New technologies will initially be evaluated in a non-operational environment. These technologies will be objectively compared not only to each other, but to currently available solutions such as EPSS and REFCL. To some extent, technologies may be alternatives, but it is also likely that they will present opportunities to improve the functionality of current solutions, and combinations of technologies may provide the best overall risk-reduction solutions. The field demonstrations through this topic may thus employ new technologies in isolation, or combinations of new and existing technologies.

Expected Outcomes

The following are the expected outcomes of the demonstrations conducted through this topic:

- Objective evaluation and comparison of various vendor products at PG&E's Applied Technology Services lab
- Improvements to various vendor products
- Field demonstration at limited geographic scale within high fire risk areas of one or more solutions, for the primary distribution system and potentially the secondary system
- Incorporation of successful solutions into PG&E's Wildfire Mitigation Plan, for broader-scale piloting and rollout after EPIC

Metrics and Performance Indicators

- False positive and false negative rates for de-energizations
- Average time between a fault and de-energization
- Percent reduction in the number of faults that cause ignitions

Primary Users and Beneficiaries

- **General public** will benefit from improved safety and air quality that results from fewer ignitions and wildfires

- **IOUs** will benefit from a more effective and efficient set of measures to manage the risks in their systems
- **Under-resourced communities**, and in particular communities at the wildland-urban interface, will benefit from reduced risk of wildfires and the associated risk of widespread destruction in their communities
- **Technology developers and manufacturers** will benefit from learnings gained through technology demonstrations that will help them enhance their product offerings

Guiding Principles

- **Safety:** Preventing faults from causing ignitions prevents wildfires, and the associated public safety risk and destruction they can case
- **Reliability:** New technologies have the potential to reduce false positive de-energizations, and be more precise with turning off customers' power only when necessary
- **Affordability:** Preventing wildfires prevents the widespread destruction and associated economic impacts they can cause
- **Environmental Sustainability:** Preventing wildfires prevents the high amounts of pollutants they release into the environment
- **Equity:** New technologies can be deployed in vulnerable communities at the wildland-urban interface, reduce the inequitable risks faced by those communities, and reduce the inequitable impacts of air quality they face during wildfires

Background, Previous Research, and Technology Trends

Ignition probability for a fault is primarily a function of the fault energy and contact with dry fuel. The fault energy is composed of the fault current for a given duration. Reducing the fault current or the duration of the fault reduces the energy and the probability of ignition. EPSS is a tool which reduces the duration of faults by using very short time delays for tripping line protective devices. The downside to EPSS has been an adverse impact to reliability with increased SAIDI and SAIFI. The standard practice during fire season is to disable automatic reclosing, so once an EPSS enabled device trips, it locks out even if the fault was momentary.

Energized wire down scenarios on PG&E's distribution circuits pose a public safety and fire ignition risk. These scenarios are difficult for conventional distribution protection schemes to detect and de-energize the wires on the ground, since PG&E's existing distribution protection scheme relies on detecting high fault current to trip protective devices. This detection scheme can respond too slowly to prevent a fire ignition from an energized wire down or may not detect the energized wire down at all in the case of a high impedance fault. REFCL has high sensitivity to ground faults and limits fault currents below 0.5 Amps, but it is technically challenging to implement and operate.

The use of 3D LiDAR technology in and of itself is not a new and innovate technology, however in the case of wildfire mitigation, implementing 3D LiDAR technology to identify approaching vegetation is a new way to implement this technology for wood pole infrastructure. PG&E has explored 2D LiDAR and has proven its effectiveness with identifying approaching trees prior to making contact with a live conductor. There are limitations with 2D LiDAR though which 3D LiDAR would address. Benefits of 3D LiDAR over 2D LiDAR are: placement of device can reside below the conductor line, reduction in the number of devices required to fully encapsulate the conductor line, ease of installation, simplicity of design, increased system reliability, reduction of maintenance costs, and power reduction. However, for any real-time LiDAR-based approach to monitoring and proactive de-energization, significant work would need to be done to develop and demonstrate a solution that is economically viable to deploy at a broad scale.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	
Generation	
Transmission	●
Distribution	●
Demand-Side Management	

16. Undergrounding Capabilities

Innovation Need

Meeting our state's climate challenges requires bold, innovative action. That is why PG&E has launched the largest undergrounding effort by a US utility, the undergrounding of 10,000 miles of distribution system powerlines located in or near high fire-threat areas, specifically to reduce wildfire risk.

While PG&E has begun to implement its undergrounding plan using existing technology solutions, there are novel ideas and emerging technologies that have the potential to increase the speed, efficiency, and predictability of undergrounding, as well as potentially extend the life of assets with intelligent monitoring. Improvements in these areas would lead to lower costs for customers, quicker reduction of wildfire risk in these areas, and maintaining longer asset life, without jeopardizing safety and reliability.

Description

PG&E will conduct technology investigations and conduct demonstrations for the following as part of this topic:

- At-surface Alternatives to Undergrounding: When excavation is required to underground certain areas of the system, it typically requires a more stringent permitting process with longer lead times or more costly construction methods. While best efforts are made in the design phase to avoid these constraints, in some cases it is not feasible to sufficiently alter route design to avoid these areas and the associated additional costs or extended permitting period. These at-surface alternatives would be used as a permanent solution, as well as for rapid deployment in emergency situations and speedy temporary rebuild after damage including from fire damage. As part of its efforts to reduce costs and increase the speed of undergrounding and restoration, PG&E will evaluate and demonstrate novel at-surface alternatives.

- Advancing Subsurface Mapping Technologies: Though significant advances have been made in subsurface mapping technology, existing methods remain unable to provide a highly accurate and comprehensive view of subsurface conditions. Even cutting-edge technologies, such as ground penetrating radar (GPR), that can more accurately detect variations in subsurface conditions require significant human effort to interpret results, rendering the technology cost-prohibitive for widespread use. As part of efforts to improve the accuracy of subsurface maps created during the undergrounding process, PG&E will evaluate and demonstrate novel at subsurface mapping technologies.
- Intelligent Monitoring of Underground Distribution Lines: The technology installed to monitor underground utility infrastructure in most cases is reactive, rudimentary, and wholly insufficient to effectively manage a vast network of cables over the course of the asset's life. These shortcomings can result in unobserved deteriorations that can lead to faults and unplanned outages. PG&E along with other US utilities have started looking at novel technologies for evaluating the condition of the underground system and predicting impending failures. These technologies include novel wired and wireless, communicating sensors with long maintenance-free lifetimes that combined with machine learning capabilities to be able to predict impending failure so that corrective action can be taken to prevent unplanned outages.
- Cost-effective Reduction and Management of Spoils from Underground Excavation: Undergrounding construction unavoidably disturbs soil at the site, generating excess spoils that must be properly disposed of. These spoils must be handled according to specific requirements and often must be hauled off-site for processing, remediation, or disposal. Moving soils back and forth for processing and disposal between off-site locations that are often far from dig sites requires time and resources that could be avoided, aiding affordability. This process is particularly costly in cases where disturbed soil contains hazardous materials. To increase affordability and reduce the environmental impact of handling spoils, PG&E will evaluate and demonstrate new at-site and other spoils management technologies.

- Novel Materials/Construction Methods for Undergrounding: The labor required for boring tunnels, excavating trenches, laying conduit, and pulling and splicing cables drives the majority of undergrounding costs. While some innovation has been made in these areas, the methods and materials used have remained largely unchanged for years. To reduce costs and help expedite undergrounding, PG&E will evaluate and demonstrate emerging construction materials and methods. Examples include: new types of conduits that allow far longer cable pulling distances between connecting enclosures; on-demand custom 3D printed structures that allow greater flexibility in routing around obstacles and in narrow or restricted rights of way; novel solutions for siting underground distribution switches, line reclosers, and regulators; new low-cost technologies for connecting secondary service to the underground system; and methods for minimizing the need for imported aggregate materials.
- Underground Resonant Grounding: This type of grounding can offer a number of safety improvements particularly for underground vaults. While widely used in Europe, underground resonant grounding is not common with North American utilities, and PG&E has no experience using it. PG&E will investigate applicability and demonstrate underground resonant grounding technology on PG&E's system.

PG&E has been and will continue to work alongside its fellow EPIC Administrators to coordinate on EPIC topics and projects to ensure non-duplication of work, to be able to collaborate on projects when possible, and to share project learnings. PG&E notes that SCE’s Hardening and Remediation topic in their EPIC 4 Investment Plan includes elements that, at a high level, overlap with elements of this topic, though SCE’s Hardening and Remediation topic is much broader than this topic. PG&E and SCE will continue to work together to ensure that undergrounding-related projects that may be pursued through their respective topics are aligned and avoid duplication.

Expected Outcomes

The following outcomes are expected:

- A viable at-surface alternative to certain types of undergrounding where excavation would otherwise be required
- More accurate subsurface mapping with a path to operationalization
- Improved underground distribution lines sensors and systems along with analytics for advanced condition monitoring and predictive maintenance capability
- Cost-effective solution for reducing and better managing underground excavation spoils
- At least one novel material or construction method for undergrounding along with a path to production plan
- Demonstration of a viable underground resonant grounding technology that improves upon the state-of-the-art underground grounding systems currently available

Metrics and Performance Indicators

- Amount of excavation avoided through at-surface solutions
- Percent accuracy improvement of subsurface maps
- Number of cable deteriorations or faults detected that otherwise would not have been found through existing monitoring systems
- Cost reduction from improved excavation spoils management
- Number of novel materials or construction methods demonstrated

Primary Users and Beneficiaries

- **Customers** would benefit from the reduced wildfire risk and service reliability improvement from a faster, smarter, more cost-effective undergrounding program.
- **IOUs** would benefit from simpler, more predictable undergrounding projects.
- **Grid operators** would benefit from higher visibility into underground infrastructure condition and ability to proactively maintain the equipment for greater reliability and safety.
- **Under-resourced communities** in high fire risk areas would benefit from an earlier reduction in wildfire risk from faster completion of undergrounding projects.

- **Technology developers and manufacturers** would benefit from having their emerging products evaluated and demonstrated and would be able to improve their products through demonstration experience and utility feedback.

Guiding Principles

- **Safety:** A simpler, more accurately mapped, project with fewer labor hours reduces uncertainty and exposure, and therefore is safer.
- **Reliability:** A better monitored and maintained undergrounding system provides more reliable service.
- **Affordability:** By reducing project cost, including labor hours, the undergrounding program is more affordable.
- **Environmental Sustainability:** A more accurate, more efficient undergrounding process requires fewer resources and enhances the environmental sustainability of the program.
- **Equity:** Vulnerable communities in high fire risk areas could have service undergrounded sooner than otherwise would be possible, reducing their exposure to wildfire risk as well as the resulting risk of potential loss of work, education, childcare. ~~.~~

Background, Previous Research, and Technology Trends

Although PG&E and many other utilities have existing, extensive underground distribution networks, the terrain and soil composition as well as other environmental and other factors make the conventional undergrounding processes extremely difficult or expensive in certain areas, including in the high fire risk areas within PG&E's service territory. Alternatives need to be explored to make installation more effective.

Fault sensing and protection against transient voltages is another area where research is showing opportunities to increase expected average life of assets. Real-time monitoring is an opportunity to see the asset's health with a plan to make proactive repairs before the asset is damaged and fails in service.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	**Topic Applicable**
Grid Operations/Market Design	●
Generation	
Transmission	●
Distribution	●
Demand-Side Management	

17. Improved Inspection Capabilities

Innovation Need

PG&E collects a wide range of data for its routine inspections through a variety of collection methods, but its processes for reviewing the collected data are almost entirely manual. Manual inspections of assets are costly, and the quality of results can vary from inspector to inspector. Processes can be made more efficient, effective, and verifiable through application of automated machine learning capabilities. PG&E has begun to develop preliminary AI technology for inspections through its Waldo platform, but it is currently limited in the types of asset deficiencies and components it can identify and has been primarily focused on Transmission system assets. Waldo also currently lacks the ability to understand the relationships across images, such as the relationship of multiple images of the same component.

Processes for updating and assessing the quality of asset information in PG&E's systems of record are also largely manual. These processes also lack the ability to gather previously missed data points when we identify new information to capture. For some of the inspection data that is collected, there is also opportunity to populate even more detailed asset attribute information (ex: insulator counts, types, etc.) in our systems of record, but this would only be feasible with additional computer vision model development and focus.

While PG&E already collects a wide range of data types for inspections, there is potentially opportunity to employ new sensors to collect additional data types to help PG&E further improve its understanding of the health of its assets and the risks along its rights of way. There is particularly opportunity around failure modes that begin to manifest within assets and are not externally apparent.

Description

This topic will demonstrate capabilities for leveraging existing inspection data and machine learning to automate inspection processes, as well as processes for updating asset records. The topic will also demonstrate new sensors that can improve the early identification of various asset failure modes.

PG&E has an extensive amount of data including imagery, video, and Light Detection and Ranging (LiDAR), other data that can help with understanding of image relationships, as well as metadata associated with each of these data types. It is collected from the ground as well as manned and unmanned aircraft for inspections of its assets and the surrounding vegetation. PG&E will leverage these and potentially other data sources to demonstrate machine learning-based capabilities for automating the inspection and issue identification process. Work in this area will build upon the preliminary capabilities in PG&E's Waldo platform. Waldo is currently only being used for the transmission system, and this topic would both build capabilities for transmission and expand into distribution. As part of this effort, PG&E will explore ways for Waldo to understand relationships between multiple images (e.g., the insulator in picture 1 is the same insulator as that in picture 2, and "this structure contains X count of insulators"). Asset issues for which to automate identification include pole lean and deficiencies in C-hooks, insulators, hanger plates, and potentially numerous other issues.

PG&E will also apply this broad array of data to demonstrating capabilities for automatically identifying assets, their precise locations, and their detailed attributes, then updating asset information in the official systems of record.

Beyond automating inspection processes and updates to asset records, this topic will explore new sensors and data elements to improve the early identification of various asset failure modes. Demonstrations in this area will focus primarily on failure modes that begin to manifest within assets and are not externally apparent. Examples that may be pursued include ultrasonic sensors, which may help to identify internal corrosion in steel poles, and X-Ray devices, which may help to identify issues in transformers such as low oil levels.

Expected Outcomes

The demonstrations conducted through these topics are expected to deliver the following outcomes:

- Enhancements to PG&E's Waldo platform and field inspection tools to automate inspection processes
- Enhancements to PG&E's Waldo platform and field inspection tools to quality check/review human inspection results
- Enhancements to PG&E's Waldo platform and field inspection tools to detect potential failure-causing damage much closer to image capture, then escalate inspections accordingly
- Enhancements to PG&E's Waldo platform and field inspection tools to quality check/review and ultimately automate the quality of image data captured (e.g. blurry images, structure photographed does not match structure of corresponding digital record, etc.)
- Processes and interfaces to asset systems of record to automate asset information updates in those systems
- Processes and interfaces to asset systems of record to quality control existing structure, asset, and failure data gathered by non-computer vision sources
- New sensors incorporated into PG&E's inspection practices to better identify incipient asset failures

Metrics and Performance Indicators

- Rates of true and false positives for asset issues flagged in automated inspections
- Rate of errors in automatically updated asset records

- Decrease in time between image capture and identification of assets and damage with computer vision vs. without
- Decrease in cost to identify assets and damage with computer vision vs. without
- Number of asset issues that can be identified by new inspection sensors that could not be identified through existing means

Primary Users and Beneficiaries

- **Customers** will benefit from greater reliability due to more effective inspections and identification and handling of system issues before they can result in outages. They will also benefit from cost reductions due to the reduced Utility operating costs from replacing manual labor-intensive inspections with automated methods.
- **IOUs** will benefit from more efficient and effective inspection processes, reduced system risk and reduced operating costs.
- **Under-resourced communities** will benefit from greater reliability and reduced exposure to hazards, particularly in the wildland urban interface.
- **Technology developers and manufacturers** will enhance their product offerings as a result of the feedback gained from the demonstration of their various sensor devices.

Guiding Principles

- **Safety:** More effective inspections and identification and handling of system issues can prevent potential catastrophic asset failures, and potentially wildfire ignitions, that would put PG&E's workforce and the public at risk.
- **Reliability:** Enhancements to proactive identification of asset risks and issues allows for proactive mitigations, which prevents failures that would cause customer outages.
- **Affordability:** Automating inspection processes will not only reduce manual labor, it also has the potential to improve the overall effectiveness of inspection processes, and addressing issues before they result in failures is less expensive than repairing or replacing failed assets.
- **Environmental Sustainability:** Improving inspections to better proactively identify and address asset issues will reduce failures that could cause wildfires.

Background, Previous Research, and Technology Trends

Waldo, PG&E's AI-informed inspections platform, was initially developed to identify damage to electric transmission structures and the assets on them, then flag this damage for human review through PG&E's Sherlock remote desktop inspection application, as a step towards the ultimate goal of fully automating inspections. In addition to many other non-AI related challenges, the initial data pipeline and AI model design struggled with accuracy. The Waldo team has addressed some of the challenges and adjusted its roadmap and product vision. Waldo is now being used to automate some limited aspects of inspection processes, such as gathering information on assets like insulator material and color, but assessment of asset damage is still done manually. The Waldo team has also developed ways to measure AI performance against human inspection results, which will help to evaluate the performance of automated inspection capabilities demonstrated through this EPIC topic.

PG&E collects a wide range of data types for inspections, including pictures, video, LiDAR, infrared, and other data elements. However, there is opportunity to employ new mobile sensors to collect additional data types to help PG&E further improve its understanding of the health of its assets, particularly for failure modes that begin to manifest within assets and are not externally apparent. Through the EPIC 3.46 - *Advanced Electric Inspection Tools* project, for example, PG&E is exploring the application of portable x-ray devices to detect rot in a utility wood poles, and there is opportunity to explore whether these same devices could be valuable for broader asset inspections, such as determining the oil level of transformers, or other uses. Other types of sensors or methods may be able to detect other internal failure modes that are difficult to detect, such as corrosion in steel poles.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	

Generation	
Transmission	●
Distribution	●
Demand-Side Management	

18. Pinpointing Fault Location

Innovation Need

While PG&E has numerous methods for identifying when there is a fault in its electric system, it can be difficult to determine the precise location of the fault. The time it takes to identify the fault location and cause slows service restoration for customers from unplanned outages as well as from EPSS events. Outages are not just inconvenient for customers, but also bring economic and public safety impacts. There is a need to improve current capabilities to provide more reliable service for our customers and the general public.

Description

This topic will demonstrate a range of new methods for determining fault location, such as using the precise timing signals available from third party fiber optics cabling located alongside to PG&E distribution lines, next generation line sensors, SmartMeters, and synchrophasors.

This topic will also demonstrate technology currently used to pinpoint the location of faults in underground transmission lines to evaluate whether it can be effective in detecting fault locations for overhead transmission lines, as well as demonstrate novel technology for determining distribution fault location by analyzing fault and mid-circuit voltages using a combination of data from existing sensors as well as from new sensors and SmartMeters.

Beyond developing methods to narrow down the geographic location of faults within the system, this topic will also explore methods for locating the specific locations of deterioration and faults within assets themselves. For example, partial discharge events in power transformers pose significant reliability as well safety risk. One way to identify potential impending catastrophic failure is through sound. This topic will demonstrate the use of multiple acoustic sensors placed on a power transformer to determine if partial discharge faults within the transformer could be precisely located. The acoustic events would be analyzed to determine not just location but size and potential severity to provide guidance on the urgency of actions needed to be taken with that transformer to avoid unplanned service interruptions. A second way to detect partial discharge events in power transformers could be through fiber optics. This topic would also demonstrate the application of fiber optic cabling to existing power transformers along with analytics to determine if these partial discharge events could be detected. Radio frequency monitoring and imaging of the power transformers would also be demonstrated to evaluate efficacy of these technologies. Depending upon the success of any of these methods on power transformers, they may also be demonstrated on certain service transformers serving critical or public safety loads.

Expected Outcomes

This topic is expected to result in the following outcomes:

- Demonstrations of novel technologies for more rapidly determining fault location in PG&E’s transmission and distribution conductors
- Demonstrations of novel technologies for sensing and locating partial discharge events within power transformers
- Informing of strategy and path to production plans for technologies that cost-effectively improve upon speed and accuracy of fault location

Metrics and Performance Indicators

- Average distance between predicted location of fault and actual location
- Reduction of the number of average minutes of determining the exact fault location in comparison to standard operational practices
- Number of partial discharge events detected and located in power transformers

Primary Users and Beneficiaries

- **Customers** will benefit from fewer outage minutes that they experience in their electric service.
- **IOUs** will benefit from being able provide more reliable electric service to their customers.
- **Technology developers and manufacturers** would benefit from feedback on their technologies so that they can improve their products; ultimately benefitting customers.

Guiding Principles

- **Safety:** The reduction of outage minutes resulting from the solutions developed and demonstrated through this topic will improve public safety.
- **Reliability:** Shorter power interruptions help improve service reliability.
- **Affordability:** Customers will experience shorter outages thereby reducing the economic impact of outages, making service more affordable.

Background, Previous Research, and Technology Trends

Much effort has been made previously to identify fault locations more quickly and accurately. Approaches using dispersed fault indicators to calculate fault location based on fault magnitude and circuit model have been attempted with some success, but investment costs and lagging technology have been impediments to greater success. With the advancement of distributed sensors, edge analytics, improved telemetry, and other novel approaches, these approaches are now becoming more within reach. Also, major advancements in smart meters are enabling the use of these widely deployed devices as edge sensors to help localize grid events. Other self-monitoring telemetry technologies that can be incorporated into new assets will help further improve reliability, though need demonstration.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable

Grid Operations/Market Design	
Generation	
Transmission	●
Distribution	●
Demand-Side Management	

19. Risk Modeling Improvements

Innovation Need

In recent years, PG&E has made strides to enhance its ability to understand system risk and make objective investment and operational decisions aimed at maximizing risk reduction. For example, PG&E has developed and applied a system risk model in support of its annual Wildfire Mitigation Plan (WMP) that is used to quantify and objectively compare the risk that is reduced by each of the initiatives and mitigation measures proposed in its plan. PG&E also applies risk models to support operational decision making, such as real-time decisions on whether Public Safety Power Shutoffs (PSPS) need to be implemented in response to dynamic environmental conditions. In addition to these applications, PG&E risk models are an important element for annual emergency response exercises and development of realistic planning scenarios.

While PG&E has made strides, there is significant opportunity to continue improving its risk modeling capabilities in a number of areas. There is opportunity to improve and expand upon the underlying asset information that the models use. There is also opportunity to make models more granular to provide more granular calculation of risk spend efficiency across potential mitigations, and support more detailed investment decisions, such as whether to underground short sections of overhead distribution instead of other mitigations, or whether to underground secondary circuits as part of larger undergrounding projects.

In addition to enhancing the underlying asset information and improving the granularity of risk models, there are also opportunities to improve PG&E's various underlying environmental forecasting capabilities. For example, PG&E's wind forecasting is a primary component of wildfire risk modeling and is currently done with 2km resolution. Higher-resolution, accurate, wind data has the potential to significantly improve various PG&E processes, including PSPS planning and implementation. Various vendors have proposed technologies and approaches that they claim can reliably improve the resolution of PG&E’s current wind forecast data, but it is challenging to objectively compare the respective merits of the various vendor offerings without conducting thorough demonstrations. In addition to improving the underlying data that drives wildfire risk modeling, there is also opportunity to improve the modeling of non-wildfire risks to PG&E infrastructure such as volcanic eruptions, earthquakes, landslides, debris flows, drought, and other events.

Description

This topic will demonstrate capabilities for enhancing the underlying asset information and making risk models more granular, providing more granular underlying weather modeling, as well as modeling of a wider range of potential natural disasters.

PG&E will explore methods of improving and expanding upon the underlying asset information that its risk models use. PG&E will also demonstrate ways to make its risk models more granular, to support more detailed selection of the most appropriate mitigation measures in narrower geographic areas. An ultimate objective is to develop a full digital twin of PG&E’s system, which would provide a common virtual model that encompasses geospatial, technical, physical, and operational information that would be accessible enterprise-wide to support myriad applications and personnel. The work through this topic would help set the foundation for such a capability.

Examples of inputs for the digital twin could include GIS information, vegetation land surveys, engineering asset database, and high-resolution LiDAR data. Together this data, for instance, could build a virtual “3D” digital model of a line segment by representing pole spacing, line spacing, vegetation clearance, and mechanical and electrical properties. PG&E's weather applications could feed wind data into this model, where other engineering application(s) could calculate line swing and risk of ignition (based on the last clearing time and growth calculation from the vegetation database). PG&E’s ADMS application could automatically identify a PSPS event by processing the model's ignition risk parameters.

With respect to improving environmental forecasting capabilities, one example demonstration would be to increase the resolution of PG&E's wind forecasting models. Numerous vendors have approached PG&E and have claimed to be able to reliably forecast wind at resolution below 1km. PG&E would conduct an objective comparison of the wind forecasting capabilities of multiple vendors using common evaluation criteria and datasets from past PSPS events. Beyond improving the forecasting of wind and other weather data that will improve wildfire risk modeling, this topic will also develop capabilities to model and monitor the vulnerability of PG&E electric and gas system to other natural hazards such as volcanic events.

Expected Outcomes

The following are outcomes expected to result from the demonstrations conducted through this topic:

- Initial planning work and foundational demonstrations on the path to ultimately a highly detailed digital twin of the electric system
- More granular weather modeling capabilities, including potentially more granular wind forecasting. Enhanced models are expected to transition into operations at the conclusion of EPIC demonstrations with minimal additional integration costs
- Implementation of new risk models for non-wildfire natural hazards, that will be used both for strategic planning and real-time monitoring

Metrics and Performance Indicators

- Amount of increase in spatial resolution of various weather modeling capabilities
- Amount of additional enterprise risk reduction, which includes wildfire risk reduction, enabled through this topic

Primary Users and Beneficiaries

- **Customers** will benefit from better Utility investment decisions that result from improved risk modeling practices and higher risk reduction for the costs they bear. They will also benefit from improved operational decisions that result from improvements to risk models and underlying weather models, such as through more targeted PSPS implementation.

- **IOUs** will benefit from improved tools that allow them to maximize system risk reduction from their operating budgets and improved operational decision making enabled by improvements to risk models and underlying weather models.
- **Under-resourced communities**, and in particular communities at the wildland urban interface, will benefit from better-informed risk reduction measures that IOUs employ to reduce the risk of fires in their communities, as well as better operational risk models that result in more targeted PSPS activations only when and where needed.
- **Technology developers and manufacturers** may improve their product offerings based on the results and learnings of the demonstrations.

Guiding Principles

- **Safety:** Improved risk modeling capabilities will broadly reduce wildfire and other risks to customer and worker safety.
- **Reliability:** Improvements to risk-informed investment planning will reduce asset failures and unplanned outages. Better operational risk models will result in more targeted PSPS activations and activations of EPSS settings only when and where needed.
- **Affordability:** Improved risk modeling is intended to guide work to mitigate more risk than would otherwise be possible. Less risk leads to fewer catastrophic disasters and therefore lower costs. Improved risk modelling also allows for improved long-term planning to ensure capital investments are appropriate up front to minimize the long-term costs and need for re-investing in the same areas due to changes in environmental factors.
- **Environmental Sustainability:** Improved risk modeling capabilities will broadly improve Utility risk mitigation measures, which will help to reduce wildfires and other events.
- **Equity:** A disproportionate amount of PG&E’s system risk is in communities in the wildland urban interface, and improvements in risk-informed investment planning and operational decision-making will benefit these communities specifically.

Background, Previous Research, and Technology Trends

As mentioned above, in recent years, PG&E has made strides to enhance its ability to understand system risk and make objective investment and operational decisions aimed at maximizing risk reduction. PG&E continues to work closely with its fellow IOUs, the vendor community, and academic institutions in these efforts. Examples include joint Utility modeling, third-party risk model assessments, climate vulnerability assessments, as well as egress, EPSS, fire break, and fire-retardant studies.

Through the EPIC 1.05 - *Demonstrate New Resource Forecast Methods to Better Predict Variable Resource Output* project, PG&E made significant strides to improve the resolution of its weather forecasting capabilities, and also developed a Fire Danger Rating System that served as the basis for PG&E’s Fire Potential Index. This project concluded in December of 2016, and there are now opportunities to demonstrate and integrate vendor product offerings for even more granular weather forecasting. In addition to improving the underlying data that drives wildfire risk modeling, there is also opportunity to improve the modeling of non-wildfire risks to PG&E infrastructure. Work in this area could enhance existing tools such as PG&E’s Dynamic Automated Seismic Hazard (DASH) system.

In recent years, utilities have been exploring the concept of creating detailed Digital Twins of their systems to support a range of use cases, and just this year PG&E started new discussions with SCE and other major North American utilities on the digital twin definition, the reference model, and use cases. The concept of a Digital Twin Model goes beyond meteorology and environmental forecasts. A Digital Twin would combine geospatial, technical, and physical characteristics together into a common model that could ultimately significantly improve PG&E’s understanding of the risks in its system. Examples of inputs for model of this type could include GIS information, vegetation land surveys, engineering asset database, high-resolution LiDAR data, as well as weather data. Many factors are beginning to make a digital twin concept more feasible, including greater access and more efficient means of capturing data such as LiDAR, improvements to the data in PG&E’s existing systems of record, and the availability of cloud environments and greater computational power for hosting such complex models.

However, creating a Digital Twin would be a significant undertaking that would have to be tackled in steps, with prioritization of specific functional elements and use cases along the way.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	●
Generation	
Transmission	●
Distribution	●
Demand-Side Management	

20. Crowdsourcing

Innovation Need

PG&E employs a wide range of inspection and situational-awareness resources including field inspectors, drones, helicopters, weather stations, and cameras to enhance its efforts to keep communities safe from wildfire and other hazards. In accordance with I.19-06-015, PG&E has also developed and released its *Report It* app in a pilot phase as an addition to its safety toolkit.

This crowdsourcing app is meant to be used by the public to send photos or videos of non-emergency safety concerns related to electrical equipment, such as vegetation posing a risk to PG&E power lines. PG&E manually reviews the imagery that is submitted to determine whether and what action needs to be taken. There is an opportunity to apply machine learning to the reports currently being submitted, to broaden crowdsourcing to partnerships with companies that may be routinely collecting valuable data in PG&E's service area, and to intake a wider range of data beyond photos and video.

PG&E’s current *Report It* app is also not meant to address emergency situations, and there is an opportunity to demonstrate tactical crowdsourcing capabilities that can be applied to support a range of emergency situations.

Description

This topic will demonstrate robust crowdsourcing capabilities to both enhance awareness of potential hazards and issues in non-emergency situations, as well as improve shared situational awareness in tactical emergency situations. Crowdsourcing will involve both the general public, as well as partnerships with private companies that routinely collect a wide range of valuable data types across PG&E’s service area. For example, fleets of self-driving cars collect Light Detection and Ranging (LiDAR) data that renders a detailed three-dimensional picture of its surroundings, which may be valuable to PG&E for both the assessment of our assets and the surrounding vegetation.

Beyond broader crowdsourcing and partnerships to increase the volume and types of data available to PG&E, this topic will develop advanced machine learning capabilities for automatic and rapid assessment of these large volumes of data.

This topic will also explore the potential compensation side of crowdsourcing, as well as the corresponding technology foundations, such as blockchain, for facilitating a high volume of micro-transactions that could provide the compensation that would encourage robust participation in the interest of public safety.

Expected Outcomes

The primary expected outcome of this topic is to have crowdsourcing platforms and processes that are ready to transition into real-time operational use between PG&E and a broad range of external participants. This will involve secure data feeds, as well secure financial transactions to the extent that compensation mechanisms are included as part of the model. Processes will also include automated machine learning-based analysis of the external data received, verification of the accuracy of the automated models, and associated clearly-defined, automated, and integrated processes for triaging, tracking, resolving, and communicating resolutions of identified issues.

Metrics and Performance Indicators

- Number or percent of issues identified through crowdsourced information that were confirmed to require intervention
- Number or percent of issues identified through crowdsourced information that were confirmed to require intervention and not otherwise detected internally by PG&E

Primary Users and Beneficiaries

- **IOUs** will leverage crowdsourced information to supplement their own data sources and improve their understanding and management of risks across the system.
- **Customers** will benefit from the cost efficiency associated with IOUs broadly leveraging a rich set of external data without incurring the costs of collecting the data themselves. Customers will also benefit from the resulting reductions in grid issues and ignitions, and improved resolution of emergency situations.

Guiding Principles

- **Safety:** Crowdsourcing information will improve Utility understanding and management of risks across the system, to further mitigate failures that could impact employee and public safety and create ignitions.
- **Reliability:** Crowdsourcing information will improve Utility understanding and management of risks across the system, to further mitigate failures that would otherwise cause outages.
- **Affordability:** Crowdsourcing information to prevent failures that could damage or destroy Utility equipment and potentially cause broader catastrophic events has the potential to result in significant avoided costs. Gathering this information from external parties may also be more cost effective than IOUs collecting the data themselves.
- **Environmental Sustainability:** Crowdsourcing information to prevent failures that may have otherwise resulted in ignitions has the potential to prevent the environmental impacts associated with wildfires.

Background, Previous Research, and Technology Trends

As mentioned above, in accordance with I.19-06-015, PG&E has developed and released its *Report It* app in a pilot phase for customers in high fire threat areas. This initial crowdsourcing capability is being used by the public to send photos or videos of non-emergency safety concerns related to electrical equipment, such as vegetation posing a potential risk to PG&E power lines. PG&E manually reviews the imagery that is submitted to determine whether and what action needs to be taken, without applying any machine learning or automation. PG&E has been building the internal tools and data science expertise that could be leveraged to derive extensive value from this data. While photos and videos are valuable data elements, other data elements such as LiDAR can also be extremely valuable. For example, within California in particular, there has been an increase in fleets of self-driving cars that collect massive amounts of LiDAR data that could be leveraged. Advances in blockchain applications beyond the digital world and into the physical world indicate the feasibility of providing the incentive framework and high volume of micro-transactions that could drive robust participation in any expanded PG&E crowdsourcing efforts.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	
Generation	●
Transmission	●
Distribution	●
Demand-Side Management	

21. Climate and Nature-Positive Operations

Innovation Need

As part of its commitment to climate action in California, PG&E will reduce its carbon emissions by 50 percent for direct and indirect operations and by 25 percent for value-chain activities not owned or directly controlled by PG&E. By 2040, PG&E will achieve a net zero energy system on the way to a climate- and nature-positive energy system by 2050.[27] The overall carbon emission reduction is the result of many contributing actions and investments, with a number of the technologies needed either ready to use or are maturing. The carbon emissions reduction will not be 100 percent by 2040; therefore, in order to achieve a net zero energy system, PG&E or its suppliers will need to also deploy, or at minimum benefit from, cost effective carbon capture, storage, and re-use technologies. There needs to be substantial technology advancement and commercialization improvement so that these technologies are ready for wide-scale deployment and materially contribute to achievement of PG&E's climate plan.

Description

PG&E will assess technology options and conduct demonstrations of climate and nature-positive solutions that, for example, may be applied to any remaining source of PG&E's direct, indirect, or value-chain-related carbon emissions~~, or use direct air capture~~. In doing so we will evaluate considerations such as capital costs, at-scale operating costs, net effects, required standards and work method changes, and storage siting and issues.

PG&E will assess technology options, conduct demonstrations, and complete analyses that will provide input and guidance for vegetation-related work. For instance, PG&E seeks to improve operational efficiency, environmental performance, and worker safety across the woody biomass value chain from locational targeting to collection, in situ processing, removal, and

27. Pacific Gas and Electric Company. 2022. PG&E Climate Strategy Report. https://www.pge.com/pge_global/common/pdfs/about-pge/environment/what-we-are-doing/pge-climate-goals/PGE-Climate-Strategy-Report.pdf.

development of value-added carbon re-use products. Improved project targeting and scoping for operational and ecosystem benefit, process automation, novel equipment demonstrations, new processes, and/or climate-positive re-use (such as renewable natural gas (RNG), hydrogen, mass timber, bio-oils, biochar, liquid fuels, and carbon sequestration/carbon credits) are potential areas for improvement.

Carbon tracking as a possible component of an EPIC project scope could lead to better understanding of how utility operations can generate verifiable greenhouse gas emissions mitigation or removal for the betterment of our customers and planet. It is possible that EPIC project(s) will reveal that compliance or voluntary carbon market buyers would like to buy into utility-related projects creating positive carbon-attributes, such as those resulting in production of biochar. Such external carbon credit purchases could potentially help co-fund and/or accelerate beneficial wildfire risk reduction work. PG&E does not currently have plans to claim (or purchase) carbon credits through EPIC projects warranting assurance of "credits that are rigorously demonstrable as real, verified, enforceable, permeant, additional, and robust against leakage." It would be the responsibility of any entity making carbon emission mitigation or removal claims to provide assurance of having met ~~this criteria~~these criteria, with transparency about protocols used in making such claims.

Through this topic, PG&E intends to understand the value, quantity, quality, and characteristics of potential climate and nature-positive opportunity, such as that represented by woody biomass value chain, and potential pathway to scale.

Expected Outcomes

This topic is expected to deliver the following outcomes:

- Demonstrations and path to production guidance for carbon and environment-positive solutions that can be applied to PG&E's direct operations and value chain
- Evaluation and demonstration of location-specific vegetation management (and hazardous fuels removal) work across benefits including wildfire mitigation, rebuild and repair avoidance, electric reliability, electric procurement cost, and/or ecosystem benefit

- Improved woody biomass-related technologies for vegetation management increasing worker and public safety
- Upgrades to woody biomass management technologies improving cost, safety, and environmental outcome profiles (including solutions relevant to cutting, densification, transportation, storage and conversion)
- Thorough understanding of woody biomass processing/conversion technologies mapped to appropriate products to demonstrate the economic and environmental value streams needed to incentivize investment in this nascent industry

Metrics and Performance Indicators

- Percent carbon emissions and/or criteria pollutant reduction enabled through widespread deployment of developed and demonstrated technologies
- Percent reduction in vegetation management worker and vehicle-related safety incidents
- Avoided damage to PG&E assets (e.g., hydro assets at risk of fire, siltation, or mudslide damage)
- Number of tons of carbon removed or offset
- Number of acres benefiting from ecosystem restoration
- Economic value enabled through widespread deployment of the developed and demonstrated carbon re-use technologies

Primary Users and Beneficiaries

- **Customers** will benefit from reduced wildfire risk, from reduced costs (e.g., from operational savings or cost offsets from value-added revenues), and from environmental outcomes (e.g., GHGs, criteria pollutants, ecosystem benefit).
- **IOUs** will benefit from reduced wildfire risk, reduced operational costs (from operational savings, cost offsets from value-added revenues), and improved worker safety.
- **Under-resourced rural communities** could benefit both from improved public safety and potential new economic opportunity associated with climate and environment-positive value chains.

- **Technology developers and manufacturers** will have opportunities to demonstrate climate and nature-positive technology, and to understand the role that utilities could in the play in future market development (e.g., as feedstock provider or offtaker).

Guiding Principles

- **Safety:** Improved vegetation management and nature-positive solutions tend to reduce wildfire risk, and also represent opportunity to improve operational field worker safety.
- **Reliability:** Improved vegetation management performance could reduce vegetation contact with wires that can cause outages, while improved fuels management could reduce wildfire spread which otherwise can impact reliability when distribution, transmission, or generation assets go offline.
- **Affordability:** New operational efficiencies and/or cost offsets from climate positive biomass conversion improve affordability.
- **Environmental Sustainability:** Through demonstration of relevant technologies there is the potential to improve GHG emissions, criteria pollutants, and ecosystem health outcomes.
- **Equity:** Development of new climate and nature-positive solutions could bring economic development opportunity to low-income, rural portions of PG&E's service area.

Background, Previous Research, and Technology Trends

Climate and nature-positive solutions are emerging and not considered commercially viable, with only a few early-stage projects ongoing or completed with limited work underway with vendors, research organizations, and governmental agencies. Some new technologies utilizing low-value woody biomass as an input are commercially available, though like carbon capture and storage technologies are at an early stage. Substantial questions can include technology selection, capital and operating costs, feedstock supply assurance, project financing, market development, permitting, and details of specific sequestration site selection. PG&E's EPIC 3.47 - *Operational Vegetation Management Through Novel Onsite Equipment* project is conducting preliminary demonstration of technologies and methods for biomass densification and conversion, but it is expected that additional technology demonstration work will be valuable to continue to improve technology options and then to most effectively integrate them into PG&E’s operations.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	**Topic Applicable**
Grid Operations/Market Design	●
Generation	●
Transmission	●
Distribution	●
Demand-Side Management	

22. Disaster Protection

Innovation Need

Although PG&E has significant capabilities available to avoid and recover from emergency situations beyond the significant recent investments in wildfire response capabilities, PG&E continues to face evolving risks such as from earthquakes, volcanic eruptions, and extreme weather, in addition to wildfires. There are new technologies that could help PG&E improve its protection from disasters, to be better able to protect those in its service area, and to be able to recover from emergencies and disasters more quickly and efficiently.

Description

This topic will enable demonstration of a range of disaster protection capabilities, such as:

- Real-time imaging of the entire service territory for improved situational awareness in any time of emergency. This includes the ability to reliably deliver imagery to responding personnel in emergency situations despite adverse conditions. The demonstration would also evaluate the applicability for other use cases, for instance the ability to improve on the speed or accuracy of ignition detections by incorporation of AI analysis of imagery.

- Augmented reality to improve situational awareness for field workers including but not limited to emergency management workers. Use cases include viewing of superimposed diagrams, instructions, and real-time equipment and system condition information by a remote worker by themselves as well as live remote consultation with an experienced operator for both operational and training purposes.
- Enhancements to earthquake protection capabilities, including methods for integrating detection within grid protective devices to trigger automatic de-energization, and other enhancements around real-time data collection and impact modeling. These efforts would leverage the existing State earthquake early warning platform.
- Enhancements to rapid coordination capabilities, damage modeling, delay curves, geo-fencing, and evaluation of impacts after major earthquakes and aftershocks occur using remote sensing technologies.
- Novel drift meter sensors for post-earthquake structural assessment. This is an emerging technology with broad potential use cases to help evaluate the post-earthquake condition related to life safety and operational impacts.
- Validation testing of novel remote sensing technologies such as Interferometric Synthetic Aperture Radar (InSAR) for early ground movement detection on a long-term (year-to-year) basis to identify impacts to utility infrastructure. This addresses multiple hazards and impacts related to earthquakes, storm-induced landslides, subsidence, and flooding.
- New assessment of vulnerability of the electric and gas system to volcanic events/hazard and modeling of impacts to infrastructure, including testing of potentially vulnerable equipment to determine fragility curves to update PG&E's relevant risk models. This addresses potential impacts from active California volcanic zones that are poorly understood at present.
- Advanced modeling of debris flow hazard and sedimentation within watersheds and its effect on operations, including modelling of future effects from climate change that

would inform mitigation strategies. This modeling improves worker and public safety awareness, emergency response, and impact mitigation.

- Enhanced communication capabilities on equipment to provide visibility into asset health and rapidly alert field and office workers. This increased visibility into asset and grid health can enable PG&E teams and emergency response teams to react quickly to impacts from extreme weather events.

Expected Outcomes

The expected outcomes from this topic are:

- Improved protection of utility facilities from seismic, volcanic, debris, and wildfire risks
- Improved situational awareness in emergency situations
- Improved emergency response capability
- Improved public safety during and following seismic, volcanic, extreme weather, wildfire, and other risks

Metrics and Performance Indicators

- Accuracy of modeled damage assessments versus actual
- Number of false negative and false positive activations of grid protective devices from monitored events
- Reduction in time to de-energize assets following the start of a seismic event

Primary Users and Beneficiaries

- **Customers** will benefit from the safety and reliability improvements realizable through this topic.
- **IOUs** will benefit from greater protection against environmental hazards and improved capability to recover quickly. Advances in predictive models and emergency response planning can be shared with IOUs leading to better communication, shared response, and consistency.

- **Local governments** will benefit from increased reliability of energy service during disasters, aiding their ability to respond.
- **Technology developers and manufacturers** benefit from having their emerging products evaluated and demonstrated and would be able to improve their products through demonstration experience and utility feedback.
- **Under-resourced communities** are often the most vulnerable to and most impacted by extreme weather events. Disaster protection helps prevent under-resourced communities from facing recovery efforts that are likely to be resource- and time-intensive. Additionally, early communication of potential emergency events can allow communities to prepare and potentially better withstand extreme weather or other emergencies.

Guiding Principles

- **Safety:** A grid is safer when it is better protected from disasters and can recover faster if a disaster does occur. ~~As part the planning phase, PG&E will identify different types of risk introduced by the demonstration of a new technology in this Research Topic, the likelihood and impact of those risks, implications to safety, scope, schedule and cost, as well as risk mitigation strategies. Where relevant, metrics around any safety and other quantifiable benefits expected to be delivered by the project's technology will be incorporated into the EPIC project business plan, updated over the course of project execution and included in the project's public-facing final report.~~ EPIC projects' safety performance will be monitored and reported in PG&E's annual Safety Performance Metrics report (SPM) and biannual Safety and Operational Metrics (SOM) report, as applicable.
- **Reliability:** A more resilient grid that is better protected from disasters will generally suffer lower damage levels and can therefore recover more quickly.
- **Affordability:** The avoidance of damage to PG&E's equipment from disasters will lead to increased affordability.

- **Environmental Sustainability:** The grid is more environmentally sustainable by being able to mitigate the consequences of wildfires through faster detection and from not requiring recovery and re-build after a disaster.

Background, Previous Research, and Technology Trends

Numerous studies have been conducted by many entities on the seismic, volcanic, wildfire, and post-fire debris flow risks, though the application of advancing technologies to adequately address the current and evolving risks lags behind such studies. Systems are currently in place to address such risks and disasters though it is known that they could be improved for the benefit of the public safety, worker safety, and electric system resiliency.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	Topic Applicable
Grid Operations/Market Design	●
Generation	●
Transmission	●
Distribution	●
Demand-Side Management	

23. Granular Attributes for Environmental Commodity Tracking

Innovation Need

When renewable energy is generated, the environmental attributes associated with that generation are separated from the underlying commodity of electricity. This creates a second tradable commodity called a Renewable Energy Certificate (REC) which represents proof that one megawatt hour of electricity was generated from a renewable resource. This certificate is used as the unit of account for tracking the rights and claims on the associated environmental attributes such as CO_2 reduction.

Since their introduction over 25 years ago, RECs have become a well-established and highly successful instrument for consumers to purchase renewable energy. Since 2004, the consumer market for RECs has grown from 1.6TWh to over 90TWh in 2020. This demand has helped foster development of new renewable energy generation, which in turn has resulted in emission reductions across the electricity system.

Despite this success, RECs remain a blunt and imprecise tool for offsetting emissions from consumer load. One limitation is that RECs are only issued monthly and are not time-stamped. However, the carbon intensity of the grid varies according to the time of day and across seasons. Because RECs do not capture this daily or seasonal variation, customers are unable to match their renewable energy purchasing to their actual load profile.

A second limitation is geography. The carbon intensity of the grid varies by location. In some locations, building new renewable resources merely displaces other renewables. Whereas in other locations, renewable energy can displace the very dirtiest of fossil fuel plants. However, RECs do not include these precise locational attributes to indicate their carbon content. The current practice is to use an aggregated system average across multiple years, and there is opportunity to improve this practice. The introduction of locational attributes would help ensure that local grid carbon displacement is considered and enable companies to better direct procurement to their areas of operation.

Description

The central purpose of this topic is to make electricity traceability more closely represent the physical reality and real-world availability of renewable energy resources. By introducing the time-stamping and precise locational attributes to renewable energy certificates, these "Granular RECs" will more accurately reflect the physical reality of the grid. This topic is designed to develop granular attributes for environmental commodities and evaluate their potential benefits such as:

- Bringing increased transparency to environmental claims
- Better matching clean energy supply with demand
- Enabling more granular carbon accounting methodologies

- Creating an additional price signal for renewable generation
- Displacing fossil generation at specific times and locations to maximize avoided emissions.
- Testing the hypothesis that an increase in flexible and non-daytime renewable generation would lead to the retirement of fossil plants, which are frequently located near rural communities

PG&E is focusing this topic on RECs because it is the most mature market for environmental commodities. However, there are other important environmental commodity markets that could benefit from this demonstration including the Low Carbon Fuel Standard (LCFS) market to support electric vehicle adoption or Renewable Identification Numbers (RINs) to support renewable fuels.

Expected Outcomes

The following outcomes are expected to result from this topic:

- A framework to issue and track Granular RECs on an hourly basis
- Application of this framework to a tracking platform which enables customers to match Granular REC procurement to their hourly load profile
- Demonstration of the integrity of environmental claims through auditing the chain-of-custody in accordance with existing standards
- Analysis of the effectiveness of Granular RECs to incentivize renewable generation during times of highest carbon intensity when it is needed most
- Testing of the hypothesis that an increase in flexible and non-daytime renewable generation would lead to the retirement of fossil plants, which are frequently located near rural communities

Metrics and Performance Indicators

- Number of participants in a Granular REC marketplace
- Incremental avoided emissions of Granular RECs over standard RECs

Primary Users and Beneficiaries

- **Customers** would benefit from accurate, granular, and timely information that would improve consumer choice regarding the origin and time of specific energy generation. Additionally, this topic is designed to support the 24/7 carbon free energy goals adopted by PG&E customers.
- **Regulators and planners** would benefit from understanding emissions profiles at specific times and locations on our grid to enact more targeted policies. Regulators would also benefit from increased fidelity of GHG emission reporting and key performance indicators (KPIs).
- **Renewable Generators** would benefit through increased incentives to export into the grid at times of high carbon intensity. Granular RECs could open market opportunities for small, distributed energy generators who would otherwise have limited access.

Guiding Principles

- **Affordability:** This topic would improve customer choice so they can identify opportunities to meet their emissions commitments in the most cost-effective way possible.
- **Environmental Sustainability:** This topic allows customers to favor options that economically improve their environmental profile.
- **Equity:** This topic would enable a solution that would accelerate usage of emissions-free energy in areas where it displaces the most carbon, typically in rural ~~or~~, disadvantaged or low-income communities.

Background, Previous Research, and Technology Trends

The state-of-the-art for RECs is built on technology and processes developed in the early 2000s:

- RECs are issued and tracked over tracking systems which issue RECs on a monthly basis with a 3–6-month delay between energy generation and physical settlement. This topic does not seek to displace existing tracking systems but rather be a companion to provide customers more granular data on the RECs settled over these systems.

- The carbon value of RECs is currently calculated using EPA's eGrid Data which measures emissions by region and is updated every 2-3 years. Currently the carbon value of RECs is calculated with emissions data from February 2021.
- CAISO tracks hourly emissions for their Balancing Authority Area but this information is not integrated in REC emissions tracking. CAISO's methodology does not use the marginal emissions approach which may be more appropriate for RECs.

The building blocks required to realize this topic's expected outcomes are maturing but there have been limited projects and companies combining these building blocks in ways that are also consumer-facing.

A Granular REC Standard was released in March of 2022. This new standard is supported by one of the largest compliance tracking systems in the country, by PG&E's peers, and by large corporate purchasers of renewable energy.

Mapping to the Electricity System Value Chain

As required per D.12-05-037, OP12, the following table indicates whether this proposed investment would benefit the defined parts of the electricity system value chain:

Element	**Topic Applicable**
Grid Operations/Market Design	●
Generation	●
Transmission	
Distribution	
Demand-Side Management	

CHAPTER 5: Administration and Governance of PG&E's EPIC Investment Plan

Collaboration with Program Administrators and Stakeholders

The CPUC's EPIC decisions require the four program Administrators to file coordinated Investment Plans. Throughout the execution of its EPIC 3 investment plan and in the development of its EPIC 4 Investment Plan, PG&E has worked collaboratively with the other three Administrators. This collaboration has included conducting conference calls, participating in each other's public workshops, and coordinating a number of in-person or phone-based joint portfolio review meetings. These efforts have been designed to coordinate Investment Plans and ensure investments were complementary and not unnecessarily duplicative.

Together, the Administrators have identified topics where more technical coordinated efforts from all the Administrators is warranted and plan to continue to share information and coordinate efforts in these areas to maximize benefits for all California customers of the IOUs. Areas of coordination will include, among others, RD&D activities related to:

- Distributed energy resources
- Long range planning
- Interconnection
- Microgrids
- New generation
- Transportation electrification

In the EPIC 4 cycle, the Administrators propose to take existing collaboration a step further by potentially executing joint projects in a number of areas as identified in the topic narratives in Chapters 2–4 above. Now that the IOUs have been given the flexibility to file their investment plans at the broader topic level instead of the detailed project level, this gives the Administrators more flexibility to align their funds and implement joint projects over the course of the EPIC 4 cycle.

The EPIC Administrators will continue to work together to address common goals, consistent with the state's energy and environmental policies and the EPIC program's updated guiding as established in D.21-11-028.[28] EPIC Administrators will also continue to coordinate scheduling, solicitation, and responses to comments and advice from stakeholders on their respective proposed and ongoing RD&D plans and programs. To this end, the EPIC Administrators will continue to share information regarding this EPIC 4 Investment Plan, as well as the EPIC 1, 2 and 3 portfolios. As projects complete, the Administrators will continue to meet to discuss project learnings and facilitate the dissemination of the results of the program efforts for the benefit of all California customers.

Furthermore, PG&E shares knowledge gained, and lessons learned with the industry through presentations or papers at conferences or electric groups/committees, such as DistribuTECH, Institute of Electrical and Electronics Engineers (IEEE), and Edison Electric Institute.

To the extent permissible, the EPIC Administrators will work together to avoid unnecessary duplication of efforts, consistent with Public Utilities Code 740.1 and 8360-8369, and to leverage the EPIC funding for the benefit of all electric utility customers. Frequent discussions among the EPIC Administrators will help to avoid duplication, identify potential projects, and facilitate knowledge sharing. Furthermore, when developing topics for this EPIC 4 plan, PG&E evaluated technology projects included in its other regulatory filings to avoid unnecessary duplication.

Treatment of Intellectual Property

PG&E will continue to administer and protect intellectual property rights in accordance with the guidelines provided in the Commission's EPIC decisions.[29]

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28. D.21-11-028, Appendix A.
29. D.13-11-025, at OP32, OP 34, and OP 50.

Project Portfolio Governance Process to Leverage EPIC Investments

Given the dynamic nature of RD&D efforts and the rapidly evolving electric industry, PG&E will continue to evolve the portfolio, as well as use project and program governance processes to identify, evaluate, select, and prioritize projects in an efficient manner.

Specifically, upon approval of its EPIC 4 Investment Plan, PG&E will employ the following process:

- Develop an objective set of criteria for scoring and prioritizing candidate projects
- Work internally to derive specific project opportunities from the higher-level set of topics in its EPIC 4 application
- Flesh out the preliminary details of candidate projects in a standardized template
- Socialize candidate projects with the other administrators, ensure non-duplication among administrators' planned efforts, and in some cases align candidate projects with counterpart projects of the other administrators
- Present candidate projects to an internal leadership committee that will score them using the established scoring criteria
- Present the resultant subset of candidate projects to the public for feedback and use that feedback to update project scope and inform the relative priority among projects. Also engage with DACs and other communities through PG&E's equity team, PG&E's Community Perspectives Advisory Council (C-PAC), and other channels to incorporate broader community feedback and identify opportunities to partner with communities to host projects that will have field demonstration components.
    - In 2022, as part of PG&E's effort to expand and deepen its CBO partnerships, and engage CBOs across the service territory to assist in reaching customers and providing households education and outreach, PG&E created a new Community Perspectives Advisory Council. C-PAC intends to increase the diversity of CBO perspectives that we are consulting with in our programs, and while the topics

for the Council are wide ranging, they are focused on customer and emerging technology programs and projects. Through engagement with C-PAC, PG&E can engage in conversations about potential EPIC projects and how best to communicate technical information to a wide range of public stakeholders. Additionally, C-PAC members share our public EPIC workshop invitations with their memberships base. This feedback and outreach can support increasing DVC and CBO participation in EPIC Workshops.

- Make final project selections, develop detailed business plans, obtain leadership approval of business plans, release funds, and launch projects. ~~introduced by the demonstration of a new technology ofthose risksmetrics around any safety and other quantifiable benefits expected to be delivered by the project's technologyupdated over the course of project execution and included in the project's public-facing~~

As a result of this process, PG&E will have launched projects related to numerous topics included in its investment plan application. For some topics, multiple projects may be pursued, whereas for other topics PG&E may not ultimately pursue any projects depending on evolving priorities as well as budget and internal resource limitations. While PG&E will work through the process outlined above to launch a large set of initial projects upon approval of its EPIC 4 plan, it may hold budget in reserve and plan to launch subsequent waves of projects further into the investment cycle. Once projects are launched, PG&E will implement a wide range of governance functions to ensure project success and comply with regulatory requirements throughout the project lifecycle. These functions are further described in the Joint EPIC Administrative Framework[30] filed by the Administrators in January of 2022.

In selecting and allocating budget to individual projects, as required by D.21-11-028,[31] PG&E will manage to the budget allocations it has established at the overarching initiative level. If

30. PG&E Advice 6487-E, Joint EPIC Administrator Advice Letter Proposal of Eligible Administrative Budget Line items.
31. D.21-11-028, OP 8.

PG&E anticipates a need to re-allocate more than 15 percent of total program funds among its initiatives, it will first file a Tier 2 Advice Letter and obtain CPUC approval before doing so.

While PG&E employed a very rigorous process to define the broad set of 23 topics in its EPIC 4 application, over the course of the cycle additional needs and opportunities may arise that were unforeseen at the time investment plan development. As such, PG&E requests that the CPUC allow the IOUs to file Tier 3 Advice Letters to request approval to add any additional topics to their plans, after their plans are approved. This would be analogous to the previous process for requesting approval to pursue additional projects when investment plans had been filed at the project level.

In addition, and consistent with the Commission's treatment of the IOUs' EPIC 3 programs in D.18-10-052[32], PG&E requests that the IOUs be authorized to fund their EPIC 4 projects for a full five years from the effective date of the decision approving their plans, rather than only through the end of 2025. This will allow for more effective sequencing of projects to allow for progressive maturation of technologies and solutions that would otherwise be limited if the IOUs were only authorized to fund projects between expected CPUC approval in the first half of 2023 and the end of 2025.

Program Budget

D.21-11-028 established each administrator's EPIC 4 program budget[33]. PG&E's budget from the decision is included below in Table 4.

Table 4: PG&E 2021-2025 Budget

32. D.18-10-052, OP 7.
33. D.21-11-028, Appendix B.

Total EPIC Budget	$925,000,000	
Total CPUC Oversight Budget	0.5% of total EPIC Budget	0.5 * $925,000,000 = **$4,625,000**
IOUs' Portion of Total EPIC Budget	20% of total EPIC Budget	0.2 * $925,000,000 = **$185,000,000**
PG&E Collection Allocation	50.1%	
PG&E EPIC Budget	50.1% of IOU share of EPIC budget	0.501 * $185,000,000 = **$92,685,000**
PG&E Administrative Budget	10% of PG&E EPIC Budget	0.1 * $92,685,000 = **$9,268,500**
PG&E Share of Oversight Budget	10.02% of total CPUC oversight budget (50.1% of remaining 20% not paid by CEC)	0.1002 * $4,625,000 = **$463,425**
PG&E Program Area (TD&D) Budget	(PG&E EPIC Budget) – (administrative and oversight budgets)	$92,685,000 - $9,268,500 - $463,425 = **$82,953,075**

As noted above in Chapter 1, PG&E does not have uncommitted EPIC 3 program funds with which to offset its EPIC 4 program budget. PG&E will administer its EPIC 4 program within a 10 percent administrative budget cap, in conducting the administrative activities described in the CPUC-approved Joint EPIC Administrative Framework. PG&E will also remit its collected portions of the CEC program budget and the CPUC oversight budget in accordance with the requirements established in previous EPIC decisions.

EPIC 4-Related Costs Incurred to Date

In complying with D.21-11-028, PG&E has incurred costs in conducting the following activities:

- Coordinating with its fellow administrators and the CPUC to develop a joint administrative cost framework, facilitating a public workshop on this framework, and finalizing and filing this framework (Ordering Paragraph 16)
- Developing its EPIC 4 Investment Plan and Application (Ordering Paragraph 7)
- Coordinating with its fellow administrators and the CEC to develop a common framework for benefits reporting, and developing and filing its corresponding EPIC 1, 2, & 3 Benefits Impact Report ((Ordering Paragraphs 12 & 13)

While D.21-11-028 determined that the "IOU Administrators will need to be reimbursed for the administrative costs incurred in preparing the benefits report in Ordering Paragraph 13 and thus the Commission should authorize the reimbursement using EPIC funds."[34] PG&E respectfully requests that the IOUs be authorized to account for the costs incurred in complying with all of the above ordered activities through its authorized EPIC 4 budget. PG&E has tracked the expenditures associated with these activities, and the expenditures through August 2022 are $200,155, with additional expenditures incurred but not yet available for reporting for September of 2022.

Procedures for Competitive Solicitation of Projects and Outreach to Stakeholders and Third Parties

Upon approval of its EPIC 4 application, PG&E intends to continue to consult regularly with other interested stakeholders and subject matter experts as part of the execution of the EPIC 4 Investment Plan. Beyond workshops and other stakeholder engagements, PG&E continues to maintain its own EPIC website,[35] and has contributed to the establishment of the joint EPIC database[36] and website to inform interested parties of PG&E's EPIC portfolio. PG&E also continues to post announcements on its broader sourcing website[37] when bidding opportunities arise for specific projects.

PG&E's selection of new strategy and/or technology partners or vendors for individual projects will continue to employ a public competitive solicitation process as the preferred and default acquisition method, in order to draw upon a broad array of external expertise and innovation. Eligibility criteria for award of TD&D funds will be determined on a project-by-project basis and

34. D.21-11-028, Conclusions of Law paragraph 4.
35. https://www.pge.com/epic.
36. https://www.epicpartnership.org.
37. https://www.pge.com/en_US/for-our-business-partners/purchasing-program/bid-opportunities/bid-opportunities.page?WT.mc_id=Vanity_bidopportunities&ctx=large-business.

PG&E will generally follow the IOU Contractor Solicitation Process and Evaluation Guidelines adopted in D.13-11-025.[38] Where a unique or specific expertise or capability is identified for an individual project, PG&E may employ sole source procurement procedures following PG&E's established procurement processes.

PG&E does not expect to use grants or loan-type contracts for EPIC projects but does not rule them out. PG&E may include "performance-based" incentives or requirements in its contracts, such as demonstrating a minimum level of operating experience and performance when demonstrating a particular technology, facility, or process in the field. As is usual for utility contracts in general, PG&E's EPIC contracts will retain audit rights for both PG&E and the CPUC.

38. D.13-11-025, Attachment 3.

CHAPTER 6: Benefits Metrics & Evaluation of PG&E's EPIC 4 Investment Plan

PG&E expects to use a combination of quantitative metrics and qualitative criteria in evaluating the potential benefits and actual results of its EPIC-funded projects. In accordance with D.21-11-028[39], PG&E has coordinated with CPUC staff and its fellow program Administrators to develop a uniform benefits analysis framework to enable the evaluation and tracking of the benefits of all EPIC projects. This framework was used as the basis for the EPIC 1, 2, & 3 Benefits Impact Report included as Appendix C of this application, and PG&E will leverage this framework going forward to both evaluate the potential benefits and quantify the realized benefits of its EPIC 4 projects.

As PG&E works to select EPIC 4 projects and develops detailed business plans for its projects, it will define the applicable sets of benefits metrics from the benefits analysis framework, define approaches for calculating each metric, conduct preliminary forward-looking estimates of potential benefits, and define plans for capturing data over the course of the demonstrations that will be needed to perform updated calculations of both realized and potential future benefits as projects near completion. PG&E has committed to quantifying, as applicable, and publicly sharing the benefits of its projects upon completion in each project's final report. PG&E will begin to provide this information for its EPIC 3 projects, as they start to close later in 2022, and for its EPIC 4 projects going forward. The benefits metrics provided in projects' final reports will also be included in the newly established joint EPIC database.

39. D.13-11-025, OP12.

CHAPTER 7: Conclusion and Next Steps

The five Initiatives in PG&E's EPIC 4 Investment Plan will be key to PG&E's ability to realize the safe, affordable, reliable, environmentally sustainable, and equitable electric grid that Californians need and deserve.

PG&E will continue to be a leader of grid innovation and improvement to the electric system as we continue the transition to a zero-carbon system that is resilient and reliable in the face of climate change, and as we continue to provide electric service that is safer every day for our hometowns. Throughout PG&E's EPIC 4 Investment Plan, PG&E has detailed initiatives and topics that will support Commission proceedings and help ensure that California achieves its environmental and energy system goals. PG&E has also addressed equity throughout the topics in its proposed EPIC 4 Investment Plan and will continue to pursue opportunities to enhance equity in our work. PG&E values the input received from the two public and two DAC-specific workshops. This extensive stakeholder engagement informed the Strategic Objectives, Initiatives, and Topics proposed within this EPIC 4 Investment Plan.

PG&E anticipates that the Commission will begin reviewing the IOUs' respective EPIC 4 Investment Plans to consider approval during the fourth quarter of 2022 and issue a final decision in the first quarter of 2023. Upon the Commission's approval of PG&E's EPIC 4 Investment Plan, PG&E will begin a rigorous process of internal planning and external coordination, including public workshops, to define its first wave of projects. PG&E looks forward to continued collaboration with the Commission, the CEC, SCE, SDG&E, and other EPIC stakeholders to align and launch sets of projects to advance the electric grid and deliver on the guiding principles of the EPIC program for the benefit of all Californians.

APPENDIX A: Summary of Stakeholder Feedback

Overview

As mentioned in Chapter 1 of PG&E's EPIC 4 Investment Plan Application, public stakeholder workshops are required at least twice per year, during the development of the Administrators' respective investment plans and during the execution of those plans. The purpose of these workshops is to contribute to ongoing coordination and understanding among administrators, external stakeholders, interested parties, and the California Public Utilities Commission (CPUC), while also raising awareness and visibility of Electric Program Investment Charge (EPIC) investments and promoting EPIC program transparency. Interested stakeholders may include: California legislature, State and Federal government agencies, utilities, California Independent System Operator (CAISO), consumer groups, environmental organizations, agricultural organizations, academic experts, industry research consortia, technology accelerators, business community, energy efficiency (EE) community, and clean energy or other industry associations.

The general themes of the stakeholder comments received during public workshops focused on general EPIC-related information, and on Utility technology gaps and demonstration priorities. Workshop slide presentations are available on PG&E's EPIC web page[40]. In addition to workshop materials, PG&E's prior EPIC Investment Plans, PG&E's EPIC Annual Reports, as well as links to the other Administrators' EPIC information, can be found there. PG&E's answers to main stakeholder inquiries made in the four workshops are in Table A-1 to A-4 below. These tables capture feedback, questions, or comments directed to PG&E specifically.

Table A-1: PG&E Responses at Joint Utilities EPIC DAC Workshop, June 21, 2022

Stakeholder	Feedback/Question/Comment	PG&E Response

- 40. https://www.pge.com/epic.

DAC Workshop Participant	Question regarding the “System Harmonics for Power Quality Investigations” topic: Are the smart meters used for the demonstration the standard meters or are they retrofitted in their hardware or software?	The smart meters used for this demonstration are a newer, more capable version of the current generation smart meters. These newer smart meters can sense, record, and communicate grid conditions with high accuracy and in the small intervals needed for these harmonics investigations.

Table A-2: PG&E Responses at the Joint Utilities EPIC Public Workshop, June 30, 2022

Stakeholder	**Feedback/Question/Comment**	**PG&E Response**
Industry Research Consortium Representative	Question regarding the “Remote Grid and Microgrid Enablement” topic: Might the research in this topic address the relatively high cost of microgrid deployment, beyond standardization of designs?	Yes. As noted, one expected outcome of this topic is a reduction in cost from the standardization of designs. Part of this topic is to investigate in what other ways that microgrid deployment can be simplified, as that can help speed interconnection and streamline completion (thereby lowering costs) for all parties.
Industry Research Consortium Representative	Question regarding the “Individual Customer Resiliency” topic: Might the include research into utility programs for front-of-the-meter assets?	Yes, the topic anticipates that a range of solutions on either side of the meter could be demonstrated, to fit the varying use cases. The Microgrid Enablement topic will also explore FTM assets for resiliency.

Industry Research Consortium Representative	Question regarding the "Long Duration Energy Storage" topic: How much work will be done in determining exactly how much long-duration storage is necessary and what the duration should be? Will there be work into assessing how long-duration needs (especially for contingencies) might be satisfied with a portfolio of short-duration assets?	Broader studies to determine how much long duration storage is necessary will be done outside EPIC, and by themselves are not appropriate as Utility TD&D EPIC projects. The demonstration of LDES technologies will help to shed light on the performance and applications of specific LDES technologies compared to specific SDES technologies.
Academia Representative	Question regarding the "Grid Scenario Planning" topic: "For those utilities such as PG&E and SCE who [operate] the non-electric infrastructure have you looked at interdependencies between non-electric and electric [infrastructure]?"	Generally speaking, yes, this is a central issue for PG&E. Also, PG&E's Grid Scenario Planning topic will develop capabilities that allow for simulating and developing strategies to address building electrification broadly, as well as zonal electrification of the gas system.
CPUC	Question regarding the "Data Analytics for Predictive Maintenance" topic: Are the data analytics in this topic related to machine learning?	Yes, the predictive analytic diagnostics rely on machine learning.

Table A-3: PG&E Responses at Joint Utilities DAC Workshop, August 25, 2022

Stakeholder	Feedback/Question/Comment	PG&E Response

DAC Representative	Question regarding the buyback of second-life electric vehicle batteries and analysis of the number of EVs, and therefore the applicability of battery buy-backs to, low-income electric vehicle owners, as electric vehicle ownership tends to cluster in higher income brackets.	The viability of deploying second-life battery energy storage systems in locations that benefit disadvantaged communities specifically will be explored. There would also be an exploration of whether there are opportunities for second-life battery energy storage system vendors to coordinate the procurement of the batteries needed for the demonstrations from these same communities, acknowledging that there may be less opportunities for this part. The communities could nonetheless be informed of a buyback option, as it can aid electric vehicle adoption if it is known that a second-life buybacks could lower the total lifetime cost of ownership of the electric vehicle.
City Representative	Comment related to the "Electric Vehicle Charging and Integration Enablement" topic and the "EV Battery Re-Use for Stationary Energy Storage" topic: We have a fleet of heavy-duty transit buses that are battery powered and in secondary life. It's exciting to see the advancement and wide range of	We expect to consider for demonstration a broad range of EV technology and solutions, including alternative charging technologies such as wireless charging, as well as battery swapping, as is described in PG&E's "Electric Vehicle Charging and Integration Enablement" topic.

	topics discussed for EPIC 4. One area for future consideration that is maybe an expansion of what's already been discussed today is the opportunity for battery swapping as it has a lot of purposes within it.	
DAC Representative	Comment: For EV-related topics, since DACs might not have high penetration of EVs that would be needed as the basis to conduct the demonstrations, look for opportunities to align EPIC funds with resources from other customer programs and Federal funding opportunities to provide communities with the EVs.	PG&E will look for such opportunities. This has been incorporated into the Equity section of PG&E's "Electric Vehicle Charging and Integration Enablement" topic.
DAC Representative	Comment: To be successful in working in DACs it is important to have partners that know and work in the area. Therefore, the importance of working with CBOs and developing some partners as projects are rolled out.	PG&E has formed the Community Perspectives Advisory Council (C-PAC) to strengthen communication with representatives of community-based organizations representing DACs as well as underserved, and vulnerable communities. As described in Chapter 5 of this investment plan, after PG&E's EPIC 4 Investment Plan is approved, for individual projects that are identified as good candidates for DAC partnership, PG&E would work through the C-PAC and community

		representatives to explore these opportunities, inform project plans, form partnerships.

Table A-4: PG&E Responses at Joint Utilities EPIC Public Workshop, August 29, 2022

Stakeholder	**Feedback/Question/Comment**	**PG&E Response**
CEC	Question about preference for laboratory vs. field demonstrations for Utility EPIC projects	When practical, field demonstrations are preferred over laboratory testing. It is dependent upon the specific situation, and often project work starts with planning followed by limited laboratory testing that then proceeds to a field demonstration. Field demonstrations are often located at existing PG&E facilities and therefore are not necessarily apparent to customers. Analytics projects often use live utility data so although they are unseen they are nonetheless field demonstrations.
CEC	Question about what budget allocations utilities have preliminarily set at the initiative level	PG&E has not set allocations at this time and will do so when the investment plan is filed on October 3, 2022.
CEC	Question about topic non-duplication and collaboration process after utility investment plans are filed	PG&E has extensively collaborated with the CEC, SCE, and SDG&E to coordinate on topics, ensure effective information sharing, avoid duplication

		of effort, and to identify synergistic opportunities for conducting projects together. Furthermore, PG&E expects that this coordination and collaboration process will continue and extend to the discussion of individual projects of each of the four Administrators after the IOUs' investment plans are filed. Specific areas initially targeted for collaboration include microgrids, long duration energy storage, and transportation electrification.
CPUC	Question regarding utility laboratories, interoperability testing, standards participation and development, and the role of the utilities	PG&E will conduct work in these areas consistent with its role. PG&E actively participates in many standardization processes, sometimes leading those efforts. PG&E and the other IOUs are in a unique position to be able to conduct interoperability testing of a wide variety of grid equipment in real-world and near-real-world operational environments. The feedback provided to the equipment vendors from these efforts helps improve the products for the benefit of all.
Academia	Question around whether the utilities have thought of establishing a utility-owned communication	PG&E developed an IEEE-compliant head-end system as part of its EPIC 3.03 DERMS project, which has

	platform for DER owners and whether it is covered in the proposed topics	enabled owners of large DERs to provide telemetry data to PG&E at low cost. PG&E will further explore enhancements to this platform, including the ability to send DERs control signals, through its “Advanced Distribution Powerflow Management” topic.
CEC	Question around whether the utilities will be pursuing any specific technologies for grid hardening and remediation.	Yes, PG&E will be addressing this through its Climate and Environment initiative, particularly its “Undergrounding Capabilities” topic, and other topics such as “Preventing Faults from Causing Ignitions” to a lesser extent”
CPUC	Question regarding the “Pinpointing Fault Location” topic: What is the innovation need? Can’t the existing systems just be expanded? and the need, and what the ideas are for improving.	The innovation need over the present systems is to: 1) improve the accuracy of the detected location of the fault, for instance on both overhead and underground conductors; 2) cost-effectively deploy such systems beyond the presently limited areas; and 3) identify faults in more types of grid equipment, such as in power transformers.

APPENDIX B: Information Summary of Demand Response (DR) Research, Development and Demonstration (RD&D) Activities

The Electric Program Investment Charge (EPIC) Decision (D.) 13-11-025 requires informational summaries of the IOUs' Research, Development and Demonstration (RD&D) activities undertaken as part of their approved Energy Efficiency (EE) and Demand Response (DR) portfolios. Pacific Gas and Electric Company's (PG&E) understanding is that the California Public Utilities Commission (CPUC) requests this information to confirm non-duplication of efforts.

PG&E's EE, DR, and EPIC Programs Are Distinct Programs with Separate Objectives

PG&E established its EE Program in 1976 and its DR Program in 1959. Each program has a distinct program focus, which is described in further detail below and is separate from EPIC's focus. Both the EE and DR programs provide program updates to the CPUC on the progress of these projects through either written reports or in person meetings. A summary of RD&D-type activities, including the purpose, funding, deliverables and progress to date, has been provided below in Tables B-2, B-3 and B-4, including PG&E's EE-Emerging Technology Program (ETP) projects, the joint Statewide EE-ETP projects, and the DR Emerging Technology (DRET) projects, respectively. The EE, DR and EPIC program owners have developed program guidelines to delineate the differing focus areas, which is provided in Table B-1.

Summary of EE and DR RD&D–Type Activities

PG&E's EE Portfolio is part of California's statewide initiative to achieve the state's EE goals by providing EE products, services and process improvements to end customers, through the use of rebates and incentives, energy analyses, and workforce training and education. Activities in the Energy Efficiency–Emerging Technology Program (EE-ETP) are not generally considered "RD&D," as they are focused on assessing, demonstrating, and deploying commercially deployed technologies. This approach differs from the focus for EPIC which targets demonstrations for pre-commercial technologies. The EE-ETP facilitates customer adoption of commercially available new and underutilized EE technologies, practices, and tools. The program is designed to help California customer -funded EE programs meet the state's energy reduction needs by identifying cost--effective measures that deliver reliable energy savings.

In general, the distinction PG&E makes between EE-ETP and EPIC programs is that EE-ETP's focuses on customer-side EE technologies and individual customer adoption via incentives, whereas the Utility's EPIC program covers non-EE initiatives and/or initiatives that incorporate/integrate EE, as well as other types of demand management (e.g., Integrated Distributed Energy Resources). The market facilitation of new technologies, a component of EE-ETP, is explicitly disallowed in EPIC for the IOUs, thereby further delineating Utility EE and EPIC programs. Finally, while EE-ETP is for both electric and gas applications, the Utility EPIC program is for electric Technology Demonstration and Deployment (TD&D) only.

PG&E's Demand Response Emerging Technology (DRET) Program is part of California's statewide program, which provides an opportunity for customers to play a significant role in the operation of the grid by changing their electricity consumption during peak periods in response to either economic or reliability signals. PG&E's DRET Program explores new technologies and applications that have the potential to enable or enhance DR capabilities and can include hardware, software, design tools, strategies, and services. The EPIC program avoids DR-only technology demonstrations, and instead focuses on integrating multiple Distributed Energy Resources (DERs), such as solar, behind-the-meter (BTM) storage, electric vehicles (EV), and potentially DR (or EE) as a resource.

In order to further delineate the focus of each program, Table B-1 summarizes the differences and similarities of the EE-ETP, DRET, and EPIC programs described above.

Table B-1: Comparison of EE-ETP, DRET, and EPIC Programs

Program Considerations	**EE-ETP**	**DRET**	**EPIC**
Does the program demonstrate grid optimization technologies or customer side technologies?	Customer Side	Customer Side	Both
Does the program demonstrate pre- commercial/not yet widely commercialized or commercialized technologies?	Not yet widely commercialized & commercially available	Commercially available	Pre-commercial or not yet widely commercialized
Does the program support electric or gas applications?	Electric & Gas	Electric only	Electric only
Does the program have a demand side focus or grid integration focus?	Demand-Side	Both (demand side for ultimate grid integration)	Both
Does the program focus on the site specific net effect on load or aggregated effect on load?	Site Specific	Both	Aggregated
What aspect of technologies does the program evaluate?	Energy savings & peak demand performance verification	Depends on assessment; Often load impact	Broad Range (Stronger focus on demonstration)
Does the program evaluate the existing program and process?	No	Sometimes	Sometimes
Does the program assess the technology capability of peak load reduction or load shifting?	Load reduction	Both	Both

Does the program have a focus of market facilitation of commercially available technologies?	Yes	Yes	No

Tables B-2 and B-3 list the activities in PG&E's EE-ETP portfolio and the Statewide EE-ETP portfolio respectively. These tables include each project's description/purpose, funding, deliverables, and progress to date. Table B-4 summarizes the DRET projects which include the projects' description/purpose, funding, deliverables, and progress to date.

Table B-2: PG&E EE-ETP Projects

Project Start Year	Project Name	Purpose	Funding	Deliverables	Progress to Date
2017	APS2 Online Limited-Time-Offer ET Assessment	The project will assess the effectiveness of a downstream, self-install approach by selling 1,000 devices to interested customers, who will be surveyed to understand install and persistence rate.	$150,000	ET Report	Completed
2017	Agricultural-Industrial Controls Market Study	Review of market adoption of VSD/Control systems for possible expansion of product offering and re-write of Work Paper.	$7,500	WP Updates	Completed
2017	Airflow Management for Data Centers	Allowing cost-effective implementation of air management in small data centers is important since the vast majority of the remaining potential for savings in data centers is in small centers. We will test air management packages in live data centers to refine the packages and the energy	$125,000	N/A	Cancelled

		modeling estimates from a 2016 PG&E study. LBNL will standardize the packages for large-scale deployment to allow deemed savings. The deliverables will include descriptions of the improved packages and a detailed implementation roadmap.			
2017	Water AMI Pilot	The effort was mandated by CPUC as part of Water/Energy Nexus; CPUC approved the scope of the project in D.16-06-010 on June 9, 2016. The project seeks to assess the value of providing customers with near real-time granular water use reporting as a means of determining how behavior and technology-based water interventions can reduce water usage, peak energy usage, and total energy usage. For the purpose of this study, PG&E and its partners, East Bay Municipal Utility District and UC Davis, will use customer meter data (at the highest	$400,000	ET Report	Completed

		resolution available) for residential electricity, gas, and water consumption, as well as targeted water and energy conservation messaging.			
2017	Energy Management Circuit Breakers - EPRI	Eaton has recently developed a new type of circuit-breaker, the Energy Management Circuit Breaker (EMCB), that fits into a standard electrical sub-panel with embedded data monitoring and ability to remotely turn the breaker on or off. After running a lab test of the circuit-breaker, EPRI is using customer field deployments to gain further understanding of the technical and market potential of the circuit breaker, in collaboration with 12 other utilities with each utility defining their own scope, use case, and learnings.	$375,000	N/A	Cancelled

		The EMCB is potentially an integrated, turnkey solution for circuit-level monitoring that needs validation as a measurement and monitoring device.			
2017	Connected Home Market and Technical Characterization Study	The project will conduct a state of the industry study of the stacked effect? in the Connected Home space, with the goal being to have a deeper understanding of the market players and value when optimized energy consumption is provided, or not provided, to residential households.	$75,000	ET Report	Completed

2018	Connected Restaurant EMS	SMB customers are high EUI establishments who often dont understand where their energy consumption comes from and thus do not have the tools to reduce their energy use. Gridpoints Building Management Systems (BMS) technology includes sub-system controls and data analytics to provide the tools necessary for such establishments to understand and reduce their energy consumption. This project will test the energy savings potential of a the SiteSage BMS technology at a one specific SMB customer site.	$200,000	ET Report	Completed
2018	HVAC Monitoring and Controls for SMB	To Be Determined	$450,000	N/A	Cancelled
2018	Connected Home Product Bundle Field Study	The study will assess the technical and customer satisfaction aspects of bundles including smart thermostats, lights, switches, and other devices.	$300,000	ET Report	Completed

2018	Development of a Laboratory Data-Based Algorithm for Horizontal Drain Water Heat Recovery Devices, and Predictions of In-Field Performance	This project evaluated H-DWHR performance and practical issues through laboratory testing of three HDWHR devices, algorithm development, and simulation studies.	$0	ET Report	Completed
2020	Sensor Based Range Hoods	The project objective is to investigate the technical and market feasibility (including consumer acceptance) of different sensor-based range hoods, with the goal of using results to inform Title 24-2025 code change proposals and other programs supported by PG&E that could benefit from an understanding of how range hoods play a role in improving indoor air quality, especially in smaller dwelling spaces. Goals include: 1) Identify existing and emerging products that use or could be adapted with integrated sensors,	$372,770	ET Report	Completed

		including after-market products for automated control of kitchen range hoods that exhaust to outdoors; 2) Assess energy and indoor air quality (IAQ) performance, economics, adoption feasibility and consumer acceptability of these products; and 3) Recommend solutions that could be included in 2025 Title 24, Part 6 code change proposals and future utility work papers			
2021	Thin-Glass Triple-Pane (TGTP) Windows Tech Intro Support	Evaluate the market-readiness, through production home builder demonstrations in climate zones 11, 12, or 13 with a limited number of incentivized homes per project, of triple-pane windows with a thin center pane of glass (≤ 2mm thick), fitting into a typical double-pane window frame with an NFRC-rated U-factor ≤ 0.22 and SHGC that will comply with the Energy Code. This project tests for	$485,000	Report	Completed

		procurement challenges, cost, and installation issues.			
2021	Climate Wizard 3 (CW3) Modeling and Insulated Duct Analysis	The CW3 is a cooling system which provides 100 percent outdoor air. Since the system relies solely on evaporating water to produce cooling, there is no compressor energy use or associated refrigerant, which allows the system to achieve very high efficiencies. This project evaluates the CW3 for both residential and classroom applications and compliments the CVRH project.	$195,408	ET Report	Completed

2021	Central Valley Research Homes (CVRH)	The CVRH project converted four existing single-family buildings in Stockton, California into unoccupied laboratory houses to study residential energy saving opportunities. Current focuses include testing the performance of VCHPs (mini-split heat pumps) at two, one is evaluating a Sanden HPWH (for space heating and hot water) and a CW3, and the fourth focuses on air-to-water heat pump performance, coupled with radiant ceiling panels, hydronic fan coils, and thermal energy storage.	$2,093,990	Expected ET Report	In process
2021	Midstream Heat Pump Water Heater (HPWH)	The project will test various strategies to engage midstream market actors and conduct an assessment to accelerate the adoption of connected unitary heat pump water heaters with controls for load-shifting for retrofit applications. Data collected will	$1,000,000	Expected ET Report	In process

		include panel upgrade needs, cost, labor information and DR aspects. This project is supported by PG&E's EE and DR Programs and will build upon the knowledge gained during prior HPWH studies.			
2021	Controlled Environment Horticulture Tech Evaluation	Investigate the energy reduction potential of lighting and controls systems that integrate HVAC with other energy end uses for CEH facilities;	$450,000	Expected ET Report	In process
2021	Villara Three-Function Heat Pump	Investigate Energy Savings Potential of three function HP system for Residential Heating, Cooling and Hot Water	$175,000	Expected ET Report	In process
2021	Induction Cooktop Loaner Program	To help support introduction of Induction Cooktops to both Residential and Commercial Market Segments. To help identify obstacles to adoption by allow customers to "try it before you buy it" Includes technical support to commercial	$257,000	Expected ET Report	In process

		food service customers utilizing the Food Service Technology Center			
2021	Advanced Water Heating Initiative and Grid Optimal Support	To Transform Residential Water heating market to HP Technology by creating demand through awareness and incentives directed at multiple points through supply channel. (Direct to customer, Dealer & retailer incentives). Project also includes placement of brand new 120v HP water heater designs intended to overcome existing home panel capacity issues. Project also includes TOU research to ensure added electric load is minimized at peak demand periods	$509,990	Expected ET Report	In process
2021	Intertek Portable Battery Testing	Conduct Performance Testing on residential battery systems	$200,000	Expected ET Report	In process
2021	XeroHome/Vistar	Existing Home Energy Modeling in in SLO and Petaluma	$466,000	Expected ET Report	In process

Table B-3: Statewide EE ETP Projects

Project Start Year	Project Name	Purpose	Deliverables	Progress to Date
2022	ET22SWE0023 - Occupancy-based Thermostats for Commercial Offices	The proposed project will assess the use of occupancy sensors in HVAC systems comprising single HVAC unit serving multiple building zones. By installing wireless connected occupancy sensors in each served space of a single system, the sensors can communicate with the system thermostat to shut off the system when all served spaces are unoccupied. For example, this could reduce energy consumption on days when teams are working from home, during lunchtime hours, or Fridays when many businesses offer modified work hours as an employee benefit. The technology can be used in both new and existing construction. For existing construction, occupancy-based thermostat will replace or be added onto existing thermostat that	Expected ET Report	In Process

		controls the single-zone HVAC unit. The thermostat can work with any type of single-zone HVAC units, which are typically constant speed units.		
2022	ET22SWE0022 - Residential Housing Characteristics Study	This California Low-Income Residential Housing Characteristics Study project proposes to address the lack of complete data on housing structures in disadvantaged communities (DAC) and Hard-to-Reach (HTR) single family residential housing. While high level data such as number of homes in DACs and other key demographic and market information (housing age, access to broadband, etc.) can be pulled from census and other research, data on the baseline physical conditions of DAC and HTR homes is lacking (i.e., structural integrity, electrical panel	Expected ET Report	In Process

		and wire capacity, and code adherence). This data is foundational to being able to both size the total available market for emerging technologies and develop effective, properly budgeted program pathways to serve and transform these communities. The results will help facilitate deployment of emerging technologies including heat pump water heaters, heat pump HVAC, smart plug loads, efficient appliances including induction stove-tops, home networking equipment, and other decarbonization measures.		
2022	ET22SWE0021 - Residential Multi-Function Heat Pumps: Product Search	This proposed technical market characterization project will complete a product search from the largest HVAC and hot water heating equipment manufacturers to identify what residential air-to-air multi-function heat pump products are commercially available or soon to be commercially available in California. This project will be a combination of primary research surveying manufacturers as well as secondary research	Expected ET Report	In Process

		through literature searches. This project will produce a list of available products and specifications including rated efficiency energy savings estimates compared to mixed fuel and all electric baselines. This product search will inform future projects to improve equipment design, validate energy efficiency through laboratory and field demonstrations, and determine costs for equipment and installation.		
2022	ET22SWE0020 - Variable Refrigerant Flow (VRF) Refrigerant Management Market Assessment	This market assessment will provide clarity on anticipated market adoption of VRF systems, the lifetime GHG emissions potential of those systems if no action is taken, and the mitigation strategies that can be implemented to maximize that environmental, economic, and social benefits of commercial heat pumps. Additionally, the project will build upon and complement the current Commercial VRF Fuel Substitution measure development activity also being performed by Energy Solutions, by bringing in new market study	Expected ET Report	In Process

		activities including stakeholder engagement and a deeper focus on new system installations.		
2022	ET22SWE0019 - Market Potential for Heat Pump Assisted Hot Water Systems in Food Service Facilities	Electrifying the building sector is a critical step towards meeting California's decarbonization goals. Water heating for food service applications represents 340M therms of gas consumption and thus presents a significant electrification opportunity through the application of heat pump (HP) assistance. For the proposed study we will conduct a market assessment of the potential for adoption of heat pump-assisted hot water systems (HPaHWS) in food service facilities. This market assessment will evaluate the total reachable market and the market penetration potential for HPaHWS. We will also address the market barriers and opportunities for adoption of HPaHWS as they currently exist. This study will occur in three phases:	Expected ET Report	In Process

		Literature search, Interviews, Numerical data collection and analysis.		
2022	ET22SWE0017 - Commercial and MF CO2-based Heat Pump Water Heater Market Study and Field Demonstration	The study will build on existing research and non-residential HPWH initiatives with a focus on the California market, policies, rate structures, efficiency programs, demand flexibility programs, and market barriers. The field study will evaluate product performance and impacts on energy, cost, and greenhouse gas emissions (GHG) of the technology relative to baseline natural gas as well as load flexibility capabilities in the context of CA rates and the new Total System Benefit (TSB) metric for EE programs. The product will be installed,	Expected ET Report	In Process

		monitored, and analyzed at two participant MF sites.		
2022	ET22SWE0010 - All-Electric Commercial Kitchen Electrical Requirements Study Evaluation	This study will identify the electrical service requirements for various sizes of foodservice facilities such as quick serve, full service, cafeterias, and hospitality. This will help understand the costs, electrical load requirements, electrical service upgrade costs, and potential electrical load growth for commercial foodservice facilities in CA in converting to all-electric kitchen designs. We would work with market actors such as design/build firms to develop prototype buildings for electrical service requirements. Once the electrical service requirements have been developed for multiple prototype foodservice facilities, cost research will be completed to determine the cost of upgrading electrical service for an all-electric kitchen. Based on	Expected ET Report	In Process

		the electrical service requirements for the foodservice prototypes, the study will estimate the increased load associated with converting all foodservice facilities in CA to all-electric kitchen designs.		

Table B-4: DRET Projects

Project Start Year	Project Name	Purpose	Funding	Deliverables	Progress to Date
2017	Lab Test to Understand Existing Technologies' Ability to meet CAISO Telemetry Requirements for PDR	to explore the technical feasibility of the second solution set: using a Zigbee to broadband gateway communicating to a cloud RIG. The lab study tested two devices: the Rainforest EAGLE and the	$100,001 to $250,000	DRET Report	Completed

		Universal Devices ISY and used Olivine's CAISO approved RIG			
2017	Title 24 – Marketing Education and Outreach	to educate and inform key market actors who will be impacted by the requirement or can exert an impact throughout the compliance industry. These include equipment manufacturers and design professionals, installers that implement the designs, acceptance test technicians that verify the proper operation, and building department staff that enforce the requirements	$100,001 to $250,000	DRET Report	Completed
2017	Telemetry Field Study	To evaluate ability for Demand Response Providers (DRPs) to meet the telemetry requirements in a cost-effective manner could unlock more DR to be bid into the wholesale market and meet the various needs of the grid	$100,001 to $250,000	DRET Report	Completed

2017	Automated Demand Response (ADR) Assessment of Residential Incentives and Technologies	to conduct a review of the PG&E's current ADR program design and extract how the lessons learned to date can provide information for further enhancement to the ADR program	$250,001 to $500,000	DRET Report	Completed
2018	Expansion of the Deemed Auto-DR Express/Fast Track Solutions	to increase automated demand response market penetration of SMB customers by expanding SMB eligible measures, adding additional facility types	$100,001 to $250,000	DRET Report	Completed
2018	Secured Data Sharing to improve residential DR programs' enrollment process	to collect information in order to create a smooth and secure customer authentication, authorization, and enrollment framework for DR pilots and programs in the future	$100,001 to $250,000	DRET Report	Completed
2018	Watter Saver Pilot	to test program implementation approaches that can be used for an actual program if the AB 2868 proposal is approved or in the alternate if the EE or DR programs leverage water heating for Energy Efficiency (EE) and DR benefits in the future	$250,001 to $500,000	DRET Report	Completed

2018	Connected Home Product Bundle Field Study	to explore the way that customers are currently interacting, and could interact, with new Energy Management Technologies (EMTs) for a variety of different energy management-related applications	$100,001 to $250,000	DRET Report	Completed
2018	Testing Statistical Sampling Methodologies and Alternative Baseline	to develop and analyze a Type-II methodology so that all residential customers may be able to participate in CAISO's wholesale markets	$100,001 to $250,000	DRET Report	Completed
2018	GHG Grid signal indicator lab test	to confirm that smart devices can be automatically controlled by a continuous/high frequency dispatch Demand Response (DR) signal (based on a combination of near-real-time GHG data from power grid operators and a forecast of grid conditions over a 30-day planning horizon) in a lab environment	$100,001 to $250,000	DRET Report	Completed

2018	Integrated Energy Efficiency and Demand Response Programs: Breaking Down Silos	to review experiences with integrated EE/DR programs. Key objectives will be to assess promising opportunities, identify barriers, and recommend supportive policies for greater integration of utility EE and DR programs that yield greater benefits to customers at lower costs than would separate programs	$100,001 to $250,000	ACEEE Report	Completed
2018	Bundling Energy Efficiency with Distributed Energy Resources	to explore projects that have bundled technologies and look at existing program offerings for efficiency retrofits, distributed energy resources, energy storage, and electric vehicle integration	$100,001 to $250,000	ACEEE Report	Completed
2019	Research project on the approach to calculate ADR control incentives	to engage in an approximately one-year research project to identify the new deemed approach and values for ADR control incentives	$100,001 to $250,000	DRET Report	Completed

2019	Evaluate 3rd parties interest on residential digital rate	to evaluate 3rd party (example: IDSM aggregators and smart energy vendors) interest in receiving residential digital rate in order to help residential customers to be successful when enrolling a dynamic rate such as TOU, EV and Smart Rate	$500,001 and up	DRET Report	In process
2020	Develop a residential ADR incentive for EV Charging Controls	to develop a residential ADR incentive for EV charging controls, this study will test EV charging controls in a field setting and measure the DR impact of such technologies	$500,001 and up	DRET Report	Completed
2020	Using voice automation technology for load management	to leverage residential voice assistants technology (such as Amazon Alexa, Google Home) to educate residential customers on energy usage and bill forecast, rates and Time-Of-Use automation/optimization, available of Internet-of-Things (IoT) and connectivity, configuration, and notification on utility information	$250,001 to $500,000	DRET Report	In process

2020	Heat Pump Water Heater barriers and mid-stream solution study	to identify potential solutions to barriers on HPWH technology, with a focus on leveraging mid-stream channels such as contractors, distributors, and retailers to increase adoption of this technology	\$250,001 to \$500,000	DRET Report	In process
2021	BTM Battery for Load Management Study	to collect data such as customer load performance and effectiveness of different algorithm during 2021 and 2022 to inform optimal program design for aggregators and customers with a BTM battery, which would help the DR team to file the 2023-2027 DR funding application in November 2021	\$500,001 and up	DRET Report	In process
2021	New DR Program/Rate designs for Ag customers	to collect data on new DR Program/Rate designs for Ag customers during 2021 in order to create a draft DR program design for agricultural and irrigation customers to be filed by PG&E in November 2021 for the 2023-2027 DR funding application	\$250,001 to \$500,000	DRET Report	Completed

2021	TOU optimization study with smart technologies	to evaluate if residential smart technologies such as smart thermostat can optimize TOU customers HVAC energy use in order to shift customers energy usage from peak to non-peak and potentially result in customers' bill saving	$500,001 and up	DRET Report	Completed
2021	Residential Battery as Virtual Power Plant (VPP) Study	to evaluates how BTM residential battery system can be used to provide value to the customers and the grid during grid emergency	$100,001 to $250,000	DRET Report	Completed
2022	Residential Smart Panel Lab and Field study	to evaluates the function of smart panel	$500,001 and up	DRET Report	In process

APPENDIX C: Pacific Gas and Electric Company's EPIC 1, 2, & 3 Benefits Impact Report

Introduction

California Public Utilities Commission (Commission) Decision (D.) 21-11-028 ordered the IOUs to:

- Coordinate with the California Energy Commission (CEC) and the Commission's Energy Division staff to develop a single, uniform benefits analysis framework and set of metrics that enable the evaluation and tracking of the benefits of all EPIC projects.[41]
- File a report documenting their success to-date of the EPIC projects under its administration, using the metrics they are ordered to create in OP 12, and in working with Commission's Energy Division staff.[42]

PG&E has coordinated extensively with SCE, SDG&E, the CEC, and Commission Energy Division staff to create a uniform framework for benefits analysis of all EPIC projects. This framework is the basis for the summaries of qualitative and quantitative benefits in this report for all of PG&E's completed EPIC 1 & 2 projects, as well as its active EPIC 3 projects.

PG&E's EPIC projects benefit its customers by providing a means to test and evaluate the integration of technologies and solutions on the electric grid. As a planner and operator of the grid, PG&E's administration of EPIC supports California's energy and environmental policies and key Commission proceedings. Examples of PG&E's EPIC program successes include the following:

- EPIC 1.01 - *Energy Storage End Uses* introduced the first utility-owned battery storage systems to help establish CAISO's new NGR market for battery participation and

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41. D.21-11-028, OP 12, at p. 57.
42. *Id.*, OP 13, at p. 58.

resolved multiple implementation issues with the NGR market model along the way. This served to enable the participation of future storage resources in the market, which now includes PG&E's own Elkhorn Energy Storage system. This project will enable $16 million per year in savings and reduce environmental emissions by 7,000 tonnes of CO_2 per year from PG&E BESS participation in the market.

- EPIC 1.05 - *Demonstrate New Resource Forecast Methods to Better Predict Variable Resource Output* deployed a new meteorological model that drastically improved the resolution of PG&E's weather modeling capabilities from 15km to 3km resolution and provided foundational improvement across a number of applications including winter storm and wildfire risk management. It is estimated that these capabilities enable the avoidance of 15.2 million customer minutes of interruption (CMI) per year and an associated $40.8 million per year in avoided customer economic impact.
- EPIC 1.14 - *Next Generation SmartMeter Telecom Network Functionalities* developed the foundation for PG&E's SmartMeter Partial Voltage Detection system, which is now deployed across PG&E's service area. The faster detection of issues across PG&E's system enabled by this technology reduces 8 million CMI per year and an associated $22 million per year in avoided customer economic impact.
- EPIC 2.34 - *Predictive Risk Identification with Radio Frequency (RF) Added to Line Sensors* demonstrated Early Fault Detection (EFD) sensors that proved to be highly effective at identifying a wide range of developing asset issues early and pinpointing the geographic locations of the issues with high precision. As a result of the successful demonstration, PG&E has begun working to deploy these sensors on 75 distribution feeders, which is expected to improve operating efficiency and reduce operating costs by $6 million per year.
- EPIC 3.03 - *Distributed Energy Resource Management System (DERMS) and Advanced Distribution Management System (ADMS) Advanced Functionality* developed and deployed a low-cost system to allow customers with large DERs to save around a total of $2.25 million per year in sending required telemetry data from their DERs back to PG&E.

- EPIC 3.11 - *Location-Specific Options for Reliability and/or Resilience Upgrades* pioneered multi-customer microgrid capabilities and operationalized the first multi-customer microgrid in PG&E's service area in collaboration with the CEC and numerous other parties. The foundational capabilities developed through this project directly defined the tariff structures and interconnection processes of PG&E's broader Community Microgrid Enablement Program (CMEP) and the Microgrid Incentive Program (MIP), which are now in the process funding the establishment of approximately a dozen microgrids. The associated reliability benefit attributed to this EPIC project is 160,000 CMI per year and an associated $3.9 million per year in customer economic benefit.
- EPIC 3.20 - *Data Analytics for Predicative Maintenance* leveraged a range of existing PG&E data sources to develop and deploy an industry-leading analytical model for identifying problems with distribution transformers with a high degree of accuracy. This model has been transitioned directly into operational use, has already led to numerous successful interventions, and is expected to save customers 1.2 million CMI per year and an associated $3.2 million per year in customer economic benefit by preventing outages caused by failed distribution transformers.

Coordination

D.21-11-028 instructed the IOUs to coordinate with the CEC and Commission staff on a common benefits analysis framework and set of metrics.[43] Starting in June 2022, PG&E and the other IOUs began conducting virtual bi-weekly meetings. As a result of these meetings, Utility staff developed the working Utility EPIC benefits framework which is designed to demonstrate the realized and potential benefits to ratepayers from EPIC research and demonstration investment. The Utility EPIC Administrators and staff presented the working benefits framework to both the CEC and Commission staff and incorporated their suggestions and comments into the final working framework. Once the benefits framework was established, the

43. D.21-11-028, OP 12, at p. 57.

EPIC staff began developing their individual Benefits Impact Reports. They continued to meet to ensure a uniform approach across the IOUs. The result of this continuous coordination process is reflected in the following PG&E Benefits Impact Report.

Benefits

The following benefits analysis framework aligns with the mandatory guiding principle of EPIC, to provide ratepayer benefits within the CPUC-defined areas of increasing reliability, improving safety, increasing affordability, improving environmental sustainability, and improving equity. Because the Utility-funded portions of the EPIC program involve the demonstration and evaluation of pre-commercial technologies, benefits are dependent on both qualitative and quantitative factors. To capture the benefits of pre-commercial demonstrations' inherent knowledge and data seeking objectives, supplemental quantification and qualification can be attributed to the following benefit areas: Adoption of EPIC Technology, Effectiveness of Information Sharing, Technology Development Progress, Support of CPUC Proceedings or State Policy, and development of Industry and/or Company Standards. The following measurement areas are the most closely aligned of the benefits in D.13-11-025 Attachment 4, although there may be additional benefits from Attachment 4 that may be applicable to future EPIC projects. The resources and tools used by the IOUs to identify, qualify, and quantify benefits are listed in Table C-1, below.

Table C-1 Joint IOUs Benefits Framework

Benefit Area	Measurement	Resources/Tools Applied
Reliability	1. Equipment service life extension 2. Outage number, frequency and duration reductions	• Final Reports • Internal Presentations • SME Estimates • ICE Calculator • Various Models

Benefit Area	Measurement	Resources/Tools Applied
	3. Reduction in system and equipment failures 4. Improved reliability to DAC customers	
Safety	1. Worker safety improvement and hazard exposure reduction 2. Public safety improvement and hazard exposure reduction 3. Safety improvements targeted towards DAC	• Final Reports • Internal Presentations • SME Estimates • https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics/light-duty-vehicle • Various Models
Environmental Benefits	• Habitat area disturbance reductions	• Final Reports • Internal Presentations • SME Estimates • https://www.californiadgstats.ca.gov/charts/

Benefit Area	Measurement	Resources/Tools Applied
	• Reduce GHG emissions ($MMTCO_2e$) • DAC Residents impacted by reduced emissions	• CalEnviroscreen 4.0 • Various Models
Economic Benefits	1. Maintain/reduce O&M costs 2. Maintain/reduce capital costs 3. Peak load reduction 4. Reduced cost of DER adoption 5. Reduced cost of DER adoption for DAC. 6. Avoided customer energy use 7. Follow-on funding to projects 8. Customer bill or interconnection savings	• Final Reports • Internal Presentations • SME Estimates • Various Models

Benefit Area	Measurement	Resources/Tools Applied
	9. CO_2 equivalent savings	
Effectiveness of Information Sharing	1. Number of industry sharing events/papers presented 2. Number of times reports are cited in scientific journals and trade publications for selected projects 3. Number of information sharing forums held 4. Stakeholder attendance at workshops 5. Results provided to standards development organizations	• Final Reports • Internal Presentations • External presentations • Other published papers • SME Estimates

Benefit Area	Measurement	Resources/Tools Applied
Adoption of EPIC Technology	1. EPIC project results referenced in regulatory proceedings 2. Number of technologies/use cases demonstrated, in direct use post-EPIC 3. Number of technologies included for funding in the GRC, or for which post-EPIC funding has otherwise formally been committed	
Support of CPUC Proceedings or State Policy	1. Specific CPUC proceedings or state mandates	

Benefit Area	Measurement	Resources/Tools Applied
Informed Industry and/or Company Standards	1. Specific standards which were created or updated	

The sections below summarize the identified benefits resulting from and expected to result from PG&E's project work in EPIC 1, 2 and 3. Every completed PG&E EPIC Project concludes with the writing of a detailed closeout report. As of the filing of this benefits and impact report, all PG&E EPIC I and EPIC II projects are complete, and all EPIC III projects are in-flight and will be completing from Q4 2022–2024. For additional information, completed project closeout reports are available on the PG&E website at https://www.pge.com/epic.

EPIC 1 Project Benefits

Project 1.01 - Energy Storage for Market Operations

In 2010, Assembly Bill (AB) 2514 directed the CPUC to set targets for the procurement of energy storage systems while noting that "there are significant barriers to obtaining the benefits of energy storage systems". Two years later in 2012, D.12-08-016 identified nine key barriers to energy storage including "Lack of Commercial Operating Experience," "Evolving Markets," "Lack of Transparency… in Wholesale Price Signals," "Lack of Well-Defined Interconnection Processes," and "Lack of Cost-Effectiveness Valuation Method" and in the following year, D.13-10-040 set the energy storage target for PG&E at 580 MW.

This project successfully addressed these barriers by utilizing PG&E's Vaca-Dixon (2 MW/14 MWh) and Yerba Buena (4 MW/28 MWh) Battery Energy Storage Systems (BESSs) to help establish and participate in CAISO's Non-Generator Resource (NGR) market model. PG&E developed and deployed a foundational automated communications and control solution to fully utilize and evaluate BESS fast-response functionalities. The two batteries from the demonstration continued to operate in production with the CAISO market well after the project concluded and are now undergoing decommissioning as they have reached the end of their useful life.

Benefits

- **Economic Benefits**
    - This project directly helped to establish CAISO's NGR market and developed automated communication and control capabilities to enable use cases including ancillary services such as frequency response (4 second response to regulate frequency) and energy arbitrage (buying electricity at low prices and selling at high prices). The project has enabled the market participation of PG&E's Elkhorn Energy Storage project (182.5 MW/730 MWh) at Moss Landing Substation. The Elkhorn system is a Lithium-Ion BESS and is the only BESS PG&E currently has participating in the CAISO market. The BESS started operations in April 2022 and its initial performance shows that ancillary services as well as energy arbitrage have significant financial benefit. Operational data from the Elkhorn Energy Storage system shows that ancillary services such as frequency regulation project to account for $9M per year in benefit and energy arbitrage projects to account for $7M per year for a total of about $16M per year.[44]
- **Environmental Benefits**
    - BESS technology displaces the need for dispatchable energy generation sources which are typically natural gas-fired power plants. Since the Elkhorn Energy Storage project is the only PG&E BESS currently participating in the market, the CO_2 reduction by charging off peak and discharging on peak/ramp is estimated to

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44. Assuming the preliminary data from Elkhorn Energy Storage project is roughly representative of its annual operation, the current economic benefits are extrapolated on an annual basis. The annual projections, before attributing to EPIC are $18M per year for frequency regulation and $14M per year for energy arbitrage, for a total of $32M per year. The calculation assumes an attribution factor of 50 percent for these benefits to EPIC 1.01, which results in the benefit of $16M per year attributed to EPIC 1.01.

be 7,000 tonnes of CO_2 reduced per year[45]. This value is only for one CAISO-connected battery system and there will likely be many CAISO-connected Battery Energy Storage Systems connected to the California grid in the future.

- **Adoption of EPIC Technology**
  - This foundational project introduced the first utility-owned battery storage resources to help establish CAISO's new NGR market/model for battery participation and resolved multiple implementation issues with the NGR market model along the way. This served to enable the participation of future storage resources in the market, which now includes PG&E's own Elkhorn Energy Storage system.
- **Support of CPUC Proceedings or State Policy**
  - Assembly Bill (AB) 2514 Energy Storage Targets
  - D.12-08-016 Adopting Proposed Framework for Analyzing Energy Storage Needs
  - D.13-10-040 Adoption of Procurement Targets for Viable and Cost-Effective Energy Storage Systems
  - R.15-03-011 Energy Storage Procurement Framework and Design Program

Quantitative Benefits Summary

Benefit Area	**Measurement**
Environmental Benefits	7,000 tonnes/year of CO_2 reduction
Economic Benefits	$16,000,000/year

45. Assuming the 730 MWh Elkhorn BESS discharges 60 percent of its nameplate energy capacity per day, charging in the day when renewables are plentiful at 0.17 tonnesCO2/kWh (from CAISO) and discharging during the peak or ramp period at 0.26 tonnesCO2/kWh (from CAISO), the GHG reduction would be 14,000 tonnes of CO2 reduced per year before attribution to EPIC. The calculation assumes an attribution factor of 50 percent for a resulting allocation of 7,000 tonnes of CO2 reduced per year attributed to EPIC 1.01.

Project 1.02 - Demonstrate Use of Distributed Energy Storage for Transmission and Distribution Cost Reduction

EPIC project 1.02 demonstrated the ability to use energy storage to delay capacity expansion while improving reliability. A Battery Energy Storage System (BESS) was deployed at the Browns Valley substation (500 kW/2 MWh). This was integrated into PG&E's Supervisory Control and Data Acquisition (SCADA) system to deliver autonomous distribution peak shaving functionality. The project has been providing benefits at the Browns Valley substation since 2017 and is still in operation. During the project, the energy storage system provided peak-shaving functionality for two peak events in 2017 during heat waves. Since then, it has provided peak shaving functionality in many peak events including in the summer of 2022.

Benefits

- **Economic Benefits**
  - The project demonstrated that it is possible to perform "distribution deferral" (also referred to as "peak shaving") to address a capacity limitation in a particular part of the electrical system and defer or eliminate the need for a capacity expansion that would only be needed to accommodate a few peak hours per year. Despite its name, distribution deferral is not limited to the distribution system as it can be applied to the transmission system as well. PG&E estimates that a future distribution deferral project between 2-10MW may save $1-3M and that a transmission deferral projects around 30 MW in size may save $5-15M[46]. This Browns Valley Project was a smaller demonstration project and is estimated to have saved around $1M in avoided distribution upgrade costs.
- **Effectiveness of Information Sharing**
  - DistribuTECH 2017: San Diego, California | February 2, 2017

46. A report called EPIC 1.02 Potential Cost Savings was created to supplement the EPIC 1.02 final report to discuss potential cost savings from distribution deferral projects. These estimated savings are from that report and are from SME estimates at the time.

- Benchmarking conference call with Puget Sound Energy | April 17, 2017
- EPRI Energy Storage Integration Council meeting: Denver, Colorado | April 21, 2017
- Benchmarking conference call with San Diego Gas & Electric Company | April 27, 2017

- **Support of CPUC Proceedings or State Requirements**
  - Assembly Bill (AB) 2514 Energy Storage Targets
  - D.12-08-016 Adopting Proposed Framework for Analyzing Energy Storage Needs

Quantitative Benefits Summary

Benefit Area	Measurement
Economic Benefits	$1,000,000

Project 1.05 - Demonstrate New Resource Forecast Methods to Better Predict Variable Resource Output

This project successfully developed and demonstrated a new mesoscale meteorological model to provide much more granular and accurate weather forecasting input to PG&E's storm damage prediction model and to other PG&E forecasting applications, such as catastrophic wildfire risk, large storms and photovoltaic (PV) generation. This model is known as the PG&E Operational Mesoscale Modeling System (POMMS) and it has improved the accuracy of forecasting for large storms, allowing for increased efficiencies in storm preparation, as well as enhanced the accuracy of identifying fire risks, helping enable improved reliability and safety. The storm damage prediction model is known as the Storm Outage Prediction Project (SOPP) and the fire danger model is known as the Fire Danger Rating System (FDRS). The POMMS model also enables leveraging of granular solar irradiance data in a new framework to improve PG&E's ability to understand the impacts of PV generation for grid management.

Before this project, the industry standard models used by PG&E for forecasting applications used a resolution of 12 km and lacked the spatial resolution needed to predict detailed surface conditions needed for storm damage modeling. EPIC 1.05 improved the resolution significantly to use 3 km resolution and made detailed modeling possible. In recent years following the EPIC 1.05 project, the POMMS model's resolution has been further improved from 3km to 2km. Over the years since the 1.05 project, other valuable applications have been found for the POMMS model's data, such as using it in Public Safety Power Shutoff (PSPS) decision making and the activation of Enhanced Powerline Safety Settings (EPSS) which has now expanded to all 25,500 distribution line miles in High Fire Risk Areas in PG&E territory.

Benefits

- **Safety**
    - Implementation of the SOPP model is correlated with an improvement in the accuracy of forecasting for large storms. This has enabled better preparation and staging of crews at appropriate locations to restore power more quickly. This resulted in:
        - Public safety benefits from faster re-energization to critical infrastructure and to residences where electricity is a medical necessity.
        - Employee safety benefits by limiting the travel time to a job location during potentially hazardous driving conditions.
    - Public safety benefitted from the more granular weather data and better modeling of fire risks from the FDRS model, which evolved into a model that PG&E currently uses today for the Fire Potential Index, the PSPS, and the EPSS modeling systems.
- **Reliability**
    - The SOPP model increased customer reliability by informing PG&E on how to better prepare and stage crews at appropriate locations to restore power more quickly during storms. Conservatively estimating that drastically increasing the resolution of weather forecasting capabilities from 15km before the 1.05 project to 3km and then ultimately to 2km, resulted in a 1 percent improvement in

storm response, this results in a reduction of 8.4 million customer outage minutes.[47]

  - Increasing the resolution of weather forecasting, including wind forecasting, has also allowed for improved fire risk forecasting and better-informed PSPS implementation. Conservatively estimating that having these better capabilities has allowed for 1 percent avoided PSPS outage impact translates to roughly 6.7 million in avoided customer minutes of interruption (CMI).[48]
  - The solar modeling system is used to improve PV load forecasting and it takes into account residential solar to ensure grid operators have the most accurate information to balance supply and demand and ensure grid stability.

- **Economic Benefits**
  - The benefits for the increased reliability from the SOPP model results in an economic benefit of $22.7 million per year.[49]
  - The benefits for the increased reliability from the better-informed PSPS modeling results in an economic benefit of $18.1 million per year.[50]

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47. This uses the total actual customer minutes of interruption (CMI) of 1.7 billion customer-minutes from all non-PSPS storm events from PG&E's 2021 Annual Electric Reliability Report (https://www.pge.com/pge_global/common/pdfs/outages/planning-and-preparedness/safety-and-preparedness/grid-reliability/electric-reliability-reports/CPUC-2021-Annual-Electric-Reliability-Report.pdf), a 1 percent reduction in storm related customer outages, and a 50 percent attribution to EPIC 1.05. This results in 8.4 million customer outage minutes avoided annually.

48. Average annual total PSPS-related CMI for distribution customers across 2020 was 1.3 billion customer minutes. Conservatively estimating that better modeling capabilities avoided 1 percent of this customer impact and using a 50 percent attribution to EPIC 1.05 results in 6.7 million customer minutes of interruption avoided.

49. Assuming a CMI multiplier of $2.69 per customer-minute and using the previously projected reliability benefits of 8.4 million CMI, the economic benefit of improved modeling for non-PSPS storm events is $22.7 million per year.

50. Assuming a CMI multiplier of $2.69 per customer-minute and using the previously projected reliability benefits of 6.7 million CMI, the economic benefit of improved modeling for PSPS events is $18.1 million per year.

    - Better fire modeling with FDRS improved PSPS and EPSS forecasting that likely resulted in fewer ignition events and less damage to property.
- **Lower GHG Emissions/Air Pollution**
    - The contribution to improved PSPS and EPSS models likely resulted in fewer ignition events and fewer fires which result in lower GHG emissions and decreased air pollution.
    - The solar modeling system is used for improved PV load forecasting, and it takes into account residential solar to allow for the increased adoption of PV resources and displacing the need for GHG generating sources.
- **Support of CPUC Proceedings or State Requirements**
    - R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans Pursuant to Senate Bill 901 (2018)
- **Informed Industry and/or Company Standards**
    - PG&E standard TD1464S - Preventing and Mitigating Fires While Performing PG&E Work

Quantitative Benefits Summary

Benefit Area	**Measurement**
Reliability	15.2 million CMI/year avoided
Economic Benefits	$40,800,000/year

Project 1.08 - Distribution System Safety and Reliability through New Data Analytics Techniques

The objective of this project was to demonstrate a visualization and decision support system to support PG&E's risk management efforts to enhance public and system safety as well as improve asset management strategies and investment plans for Electric Operations (EO). The software application developed was the System Tool for Asset Risk (STAR). The concept of STAR is to integrate electrical asset and system data from multiple sources to calculate individual asset and system risk scores based on severity of risk and probability of occurrence.

STAR is currently available in PG&E's ATLAS, which is an Information Technology (IT) integrated portfolio management system and system of record. STAR is used by PG&E electric distribution and is an analytics application now under the name APP-1889 Tool for Asset Risk. It currently is on the Amazon Web Services (AWS) platform and there are plans for it to be moved to PG&E's central Foundry platform.

Benefits

- **Safety**
    - The scoring of individual asset and system risk through the STAR tool helps to enable focusing on higher risk assets, and the identification of work that has the greatest likelihood of improving public safety.
- **Reliability**
    - The STAR platform developed through this project provides improvements to the calculation and visualization of asset system risk, which in turn enables the development of improved asset strategies to improve system reliability.
- **Economic Benefits**
    - Improvements in the asset risk quantification improve prioritization of risk mitigations and enable more efficient allocation of resources and cost reduction.
- **Support of CPUC Proceedings or State Requirements**
    - Risk Assessment and Mitigation Phase (RAMP)[51]

51. https://docs.cpuc.ca.gov/PublishedDocs/SupDoc/A2006012/2881/342386992.pdf.

Project 1.09A - Test New Remote Monitoring and Control Systems for Existing Transmission & Distribution Assets: Close Proximity Switching

In 2016, PG&E had over 20,000 oil filled sub-surface 200-amp, three phase Load Break Oil Rotary (LBOR) switches in its underground distribution system. PG&E estimates there were approximately 900 LBOR switches without oil level indicators and another 1,400 pre-1972 units which were considered high risk due to their age and the lack of knowledge of the condition of the oil inside the tank (even with an oil-level indicator). Traditional operation of LBOR switches required an employee to manually stand over the enclosure, use an insulated tool called a "hot stick", and turn the switch nob off or on. Although the hot stick protects the employee from electric shock, the employee can still be potentially injured if a failure/explosion were to occur due to low oil, mechanical fatigue, or dielectric integrity of the fluid. Failed oil switches have resulted in injury events, triggered customer outages, and/or caused property damages.

This project focused on increasing system reliability and improving the safe operation of three-phase Load Break Oil Rotary switches, which are used for making or breaking the path in an electrical circuit. In both a lab and field setting, this project successfully demonstrated and evaluated various robotics that would allow PG&E workers to remotely operate certain subsurface or underground (UG) oil switches. As a result of this EPIC project, PG&E subsequently purchased 106 remote switching devices which were distributed across the territory. It is now a company standard to only operate energized LBORs without sight glasses with the use of the remote operator equipment successfully demonstrated by EPIC 1.09A. This important safety device provides an interim solution during the implementation of a multi-year switch replacement program with the goal of completing all LBOR switch replacements by 2040.

Benefits

- **Safety**
  - Increased employee safety during sub-surface oil-filled switch operations by eliminating the need for an employee to perform manual switching by use of a "hot stick".

    - Increased public safety since the operator has better visibility of pedestrians when he/she is ready to execute the switching command remotely.
- **Reliability**
    - Should a circuit failure occur, this device ensures that PG&E has the ability to confidently and safely operate Load Break Oil Rotary (LBOR) switches to reduce customer outage/interruption time.
- **Informed Industry and/or Company Standards**
    - PG&E created or amended guidance documents to include close proximity switching devices in operations. The relevant standards are:
        - TD-2908P-01 – Distribution Switching Procedures
        - TD-2908P-01-JA280 –Remote Operator for Load Break Oil Rotary (LBOR) Switches
        - TD-2908M – Electric Distribution Field Switching Manual
        - 039954 – Installation of 200-Amp Subsurface Sectionalizing Switches
        - TD-2908B-008 – Load-Break Oil Rotary (LBOR) Switch Operating Procedure
- **Adoption of EPIC Technology**
    - PG&E initiated a General Rate Case (GRC) request for funding totaling $600,000 and this resulted in the purchase of 106 remote switching devices which were distributed across the territory according to the number of LBORs in operation in each division.

Project 1.09B/10B - Test New Remote Monitoring and Control Systems for T&D Assets/Demonstrate New Strategies and Technologies to Improve the Efficacy of Existing Maintenance and Replacement Programs

This project successfully demonstrated methods of evaluating and potentially extending the longevity, resiliency and data integrity of Supervisory Control and Data Acquisition (SCADA) condition-monitoring components over time. The overall strength of the monitoring and communication systems currently installed across the distribution network was confirmed and methods for improving the life and data integrity of its components were demonstrated. Real-time condition monitoring of this system provides a key input to support proactive mitigation of equipment-related issues.

Benefits

- **Safety**
    - Ambient temperature and oil sensors are designed to alarm upon conditions such as overheating of the equipment. Overheating could result in asset failure, potentially resulting in a safety risk. A well-functioning monitoring system reduces this safety risk.
- **Reliability**
    - The project confirmed that physical connections installed in SCADA systems are generally reliable and resilient. It also highlighted conditions where physical connection issues could occur such as in high humidity environments and with bare wire connections as opposed to pinned connections.
- **Economic Benefits**
    - Extending the life of condition monitoring equipment may reduce the life cost of installation, maintenance, repair, and replacement of this equipment. Additionally, being aware of potential problems with network equipment helps PG&E respond to required repairs before asset failures occur and can potentially

reduce the overall cost of operating the distribution network system by extending the life of major assets.

Project 1.09C - Test New Remote Monitoring and Control Systems for T&D Assets, Discrete Series Reactors

This project successfully demonstrated new Discrete Series Reactor (DSR) technology deployed directly onto transmission conductors to detect potential overloads and increase line impedance to shift this load to parallel facilities. These devices can potentially enable optimization of line flows, mitigation of overloads, and delay of costly new transmission line or reconductoring projects.

Benefits

- **Safety**
    - Transmission line overloads can potentially cause asset damage or create a safety hazard with the line. DSRs can be deployed directly onto transmission conductors to detect potential overloads and increase line impedance to shift this load to a lower load conductor.
- **Reliability**
    - Some PG&E transmission lines experience overloads following n-2 or n-1-1 outages that are mitigated by the use of Special Protection System (SPS) load tripping. The use of DSRs on such a line could reduce the need for SPS load tripping, thereby potentially reducing reliability impact.
- **Economic Benefits**
    - Currently, mitigation of transmission line overloads often leads to investments to increase capacity such as reconductoring the line. DSRs could be implemented to defer the need for a higher cost transmission capacity upgrade, reducing the cost of overload mitigation. As compared to traditional transmission investments, DSRs can be deployed several years faster at a significantly lesser cost.

Additionally, DSRs offer portability and flexibility, whereas traditional upgrades are permanent installations.

- **Adoption of EPIC Technology**
    - The project transitioned to production with the installation of 90 DSRs on the Los-Positas Newark 230kV transmission line, which reduced line flow and balanced the three phases. PG&E has adopted the DSRs as a part of the Transmission options to be considered when reviewing capacity needs.

Project 1.14 - Next Generation SmartMeter Telecom Network Functionalities

This project evaluated the radio mesh telecommunications network that connects SmartMeter devices across PG&E's territory, including demonstration of new potential use cases for SmartMeters and the network. The project created a methodology to determine available bandwidth, tested a variety of smart grid devices to demonstrate their potential to leverage the network for communications, and demonstrated potential enhancements to the existing outage reporting capabilities of SmartMeter devices.

Many programs and capabilities originated from this one project such as the Smart Streetlights and Smart Poles demonstration, the Next Generation Network Hardware, Transformer Monitoring Devices, the SmartMeter Partial Voltage Detection capability, and Phase Identification which led to EPIC 2.14.

Benefits

- **Safety**
    - This project developed the foundation for PG&E’s SmartMeter Partial Voltage Detection capability that has subsequently been deployed across PG&E’s system and allows for automated detection of wires down events and other grid issues through the SmartMeter network, and faster resolution to minimize the risk to

the public. The technology is useful for identifying the exact locations of faults for first responders.

- **Improve Reliability**
  - This project increased the work done analyzing outage logs and this helps identify the scope of outages more quickly. The project also demonstrated technologies that provide greater reliability through improvements in outage reporting, distribution automation control and telemetry, and monitoring and control of the electric grid.
  - The capabilities developed through this project evolved into PG&E's SmartMeter Partial Voltage Detection system, which is now enabled across PG&E's service area. When this system detects a fault first, it beats the other available methods by approximately 20 minutes.
- **Economic Benefits**
  - The quicker detection of downed wires and other grid issues results in a faster restoration of power to customers. Since the system is deployed across all the territory, this corresponds to a SAIDI reduction for the system which results in an estimated 8 million in reduced CMI per year and corresponding economic benefit of roughly $22,000,000 per year.[52]
  - Leveraging the SmartMeter Network for non-metering applications and devices (that would otherwise require a separate communications network) has the potential to lower costs for smart grid devices and applications that can help

52. This assumes that the improvement in time for outage detection is 20 minutes when partial-voltage detects the outage first (SME estimate) and applies it to the 5.5 million customers in PG&E territory. Conservatively, partial-voltage detection identifies the fault first 15 percent of the time (SME estimate). Because enhancement of this capability continued after the EPIC project, 50 percent of the calculated benefits are attributed to this EPIC project. With a 50 percent attribution to EPIC 1.14, this results in an average outage reduction of 1.5 minutes and a corresponding estimated 8 million in reduced CMI per year. Using an outage multiplier of $2.69 per customer-minute, this results in $22,000,000 per year in economic benefit since this technology is deployed across PG&E's service area.

PG&E to deliver energy safely and efficiently. Innovative metering solutions such as Smart Streetlights and Smart Pole Meter can enable PG&E to more accurately meter electricity use. The SmartMeter Partial Voltage Detection capability was patented, and subsequently licensed, with the potential for significant royalties over the next five years that will be returned to customers.

- **Reduce GHG Emissions, Air Pollution, or Other Health Impacts**
  - The SmartPoles, by reducing hops, free up bandwidth to allow integration of other DER and connected smart devices to the grid.
  - There is a future potential application of enabling EVs. There is discussion with cities and regulators on how to incorporate EV chargers in light poles to enable streetside EV charging.
- **Adoption of EPIC Technology**
  - The Smart Streetlights and SmartPole demonstration deployed thousands of smart poles in the San Jose and Cupertino area. These SmartPoles are easy to integrate with other devices, such as the 5G communication network, which requires more cells to operate. Previously, the electric utility would require telecom companies to find their own source of power. This project enabled 5G customers to be able to connect to the network more easily.
  - This project developed significant intellectual property, as well as multiple patents and license agreements with external vendors. For example, this project developed the foundation for the capability to use the SmartMeter network to monitor for partial voltage conditions that are indicative of wires down events. PG&E has both deployed this capability in production internally, and has licensed this capability to a large vendor, who will in turn provide it to potentially numerous other utilities. Also, the “Smart Pole Meter” developed in the project, which allows PG&E to appropriately meter telecom equipment attached to streetlights, has been patented and licensed to two vendors, enabling future revenue for PG&E when cities partner with these vendors to become “Smart Cities” with expanded connectivity.

- The SmartMeter Partial Voltage Detection capability is now deployed across all of PG&E's service area. The Restoration Dashboard was transitioned to production, and the Smart Pole Meter has been deployed at limited scale, including in the city of San Jose. The project also provided insights and lessons about how to improve operations for 2020 GRC, Chapter 6: Metering.

- **Support of CPUC Proceedings or State Requirements**
    - R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans

Quantitative Benefits Summary

Benefit Area	Measurement
Reliability	8,000,000 CMI/year avoided
Economic Benefits	$22,000,000/year

Project 1.15 - Demonstrate New Technologies and Strategies That Support Integrated "Customer-to-Market-to-Grid" Operations of the Future

This project demonstrated a technology platform to visualize grid operations data to improve both real-time and short-term operational decisions, such as outage anticipation, construction planning, circuit loading research, and emergency operations. The project developed key data, system, and user experience learnings through integrating more than 20 data sources into a single visualization tool allowing users to view complex data sources in ways that were not possible through current solutions. This project formed the foundational learnings which will allow PG&E to potentially explore other complex situational awareness tools and applications to allow users to target information to help manage changes on the grid.

Benefits

- **Safety**

- The Distributed Generation Research, Circuit Loading Research, and Outage Anticipation use cases could allow operators to identify potentially dangerous reverse power flow from distributed generation assets during circuit outages.

- **Reliability**
  - The information displayed on the Interactive Map and the Outage Anticipation use case could enable grid operators to dispatch resources more effectively. Access to better and fresher data could support more effective early warnings, reduce power quality complaints, and accelerate power restoration activities.

Project 1.16 - Demonstrate Electric Vehicle as a Resource to Improve Grid Power Quality and Reduce Customer Outages

This project successfully developed and demonstrated a new Vehicle On-Site Grid Support System (VOGSS), for utility-grade power export from Plug-in Hybrid Electric Vehicle (PHEV) fleet trucks. This new technology enables a source of mobile power that can connect directly to distribution circuits, minimizing the impact of an outage for common preventative maintenance tasks such as transformer replacements. Additionally, VOGSS can provide power to facilities in emergency events, maintaining or quickly restoring service to customers.

Benefits

- **Reliability**
  - This project was executed to explicitly enable more resilient and reliable power through the substitution of truck exported power for the utility grid when a planned shutdown is needed. When the grid is down from unplanned events, VOGSS can help enable with localized re-energizing prior to a future permanent repair.
- **Economic Benefits**
  - VOGSS leverages a multi-function tool used in lieu of either greater outage exposure or increased investment in dedicated generator sets (less capital

efficient to buy another stand-alone equipment asset). Additionally, EPIC 1.16 supports the case for leveraging electric vehicles in utility fleets. Cost savings are primarily accounted from the operating savings from a plug-in hybrid electric drive system. The drive system exploits the use of lower-cost stored grid electricity as an offset to more expensive exclusively fossil-fuel-based mobility.

- **Environmental Benefits**
    - VOGSS offers a cleaner alternative to fossil-fuel based backup generation.

Project 1.18 - Demonstrate SmartMeter-Enabled Data Analytics to Provide Customers With Appliance-Level Energy Use Information

This project conducted a demonstration to understand and compare disaggregation vendors' ability to itemize monthly appliance-level usage for residential customers, as well as their current analytical capability and accuracy of their energy disaggregation software. Additionally, this project surveyed customers to understand their perception of the end-use energy presentations and the value of the disaggregated data.

Ultimately, the technology was determined to not yet be mature enough to provide to customers. The results did not achieve the disaggregation that was hypothesized at the beginning of the project. In this finding, PG&E was able to understand the current state of the technology and avoid investments that would not be beneficial to customers.

Benefits

- **Economic Benefits**
    - This demonstration identified limitations in vendors’ abilities to itemize usage. Upon the improvement of the load disaggregation capabilities, customers will be able to manage their usage more effectively and ultimately, lower their electricity costs by understanding the underlying drivers of their electricity usage. Additionally, the learnings from disaggregated billing can be used to

inform program and product designs for energy efficiency, demand response, and other programs, which may produce lower costs to customers.

Project 1.19 - Pilot Enhanced Data Techniques and Capabilities via the SmartMeter Platform

This project successfully demonstrated new ways to leverage the SmartMeter platform to provide greater visibility and granularity to additional SmartMeter data. The project proved the ability to collect power quality data and potentially enable a proactive response to address customer satisfaction concerns on voltage issues. The project also connected difficult to reach meters to the AMI network to potentially reduce manual meter reading operation and maintenance costs. Finally, the project improved the ability to identify "Line Side Tap" scenarios to improve the efficiency and effectiveness of investigating energy diversion cases and to mitigate safety hazards for customers, the public, or PG&E.

Benefits

- **Safety**
  - This technology can be used to identify unsafe energy diversions. Removing these diversions, known as "line taps", reduces house fires and the risk to people who make the connections since an unauthorized line tap requires work on a live electrical connection.
  - This technology led to other projects such as Sensor IQ that uses non-billing data such as voltage. PG&E's Electric Operations is exploring how to use this data to identify wire down conditions or monitor for overloaded transformers.
- **Reliability**
  - Giving visibility to more granular voltage data than was previously available assists in meeting CPUC Electric Rule 2 voltage service requirements for both line-to-line and line-to-neutral voltages. Meeting the voltage requirements allows the customer and utility equipment to operate properly and reduces

potential damage from over- or under-voltage. PG&E’s power quality team still uses the data sources obtained from this project.

- **Economic Benefits**
  - Radio communications technologies that provide the AMI network with a longer range allows over-the-air operations rather than field visits for those meters that were outside of the AMI network coverage. This eliminates the cost of monthly manual meter reading, as well as the need for ad-hoc visits.
  - The project can be used to identify energy diversion (theft) which would require ratepayers to cover the difference in charges. The project team worked with PG&E’s revenue assurance department to design a voltage level for when to send someone to investigate further. Revenue assurance still uses the data sources created by this project.

Project 1.21 - Pilot Methods for Automatic Identification of Distributed Energy Resources (such as Solar PV) as they Interconnect to the Grid to Improve Safety & Reliability

This project focused on developing and demonstrating technology to identify existence of PV systems using SmartMeter and other data not otherwise recorded in PG&E's interconnection database. Additionally, the project explored the ability of detecting underperforming or malfunctioning PV systems. The project was able to develop key inputs necessary to identify a PV system, filter for those identified systems with unauthorized interconnections, support high quality interconnection records by validating the size of PV systems, understand the limitations in the ability to detect if a PV system is underperforming or not functioning, and established a process to engage with solar customers to provide appropriate notice.

Benefits

- **Safety**

- The algorithms developed by this project accurately predicted PV system sizes as well as unauthorized interconnections. Customers without an authorized interconnection may pose a risk to the components of the equipment and facility of the customer. Equipment failure can happen to various DG components, such as PV modules, inverters, circuit combiner, disconnecting, protection devices, and connectors. Equipment faults or over-heating can also ignite the combustible materials near the generator, causing fire damage to equipment and property.

- **Reliability**
  - The algorithms developed by this project accurately predicted PV system sizes as well as unauthorized interconnections. Underreported or inaccurately reported interconnections could lead to voltage fluctuation problems or Rule 21 violations, as well as other reliability and planning issues. Improving the accuracy of known PV interconnections, sizing and performance can improve the ability to identify root causes for voltage fluctuations. Additionally, reliably predictable generation profiles at geographically granular levels are essential for forecasting and planning purposes to proactively plan system upgrades or deferrals, if needed.
- **Economic Benefits**
  - By detecting that an existing solar customer has an unauthorized interconnection, PG&E enables customers to participate in the Net Energy Metering (NEM) rate, reducing customer costs.
- **Adoption of EPIC Technology**
  - The PV detection algorithm developed in the project successfully identified 53 suspected unauthorized interconnections (UIs) out of a sample of 72,306 customers used for the project, with model precision of 98.52 percent. Subsequent to the EPIC project, the algorithm was applied across the service territory, and identified over 2000 suspected UIs, which facilitated PG&E's coordination with these customers.

- **Effectiveness of Information Sharing**
    - PG&E filed patent US 10,577,720-B2 on the technology developed for this EPIC project.
- **Support of CPUC Proceedings or State Requirements**
    - R.11-09-011 Rule 21, Smart Inverter
    - R.17-07-007 Streamlining Interconnection of Distributed Energy Resources and Improvements to Rule 21

Project 1.22 - Demonstrate Subtractive Billing with Submetering for EVs to Increase Customer Billing Flexibility

This project was part of a California Statewide effort to demonstrate and evaluate the use of Electric Vehicle (EV) submetering to provide EV owners access to electricity at a less expensive electric rate—without having to install an additional utility meter to an existing service. This project also assessed EV customer demand for submetering and the customer experience with submetering.

Benefits

- **Reliability**
    - Subtractive billing via third-party submetering has the potential to improve the monitoring and management of EV charging load, which can contribute to improved system reliability. However, EPIC 1.22 showed that the demonstrated approach to EV submetering was not ready to scale to the entire state at the time of the project.
- **Economic Benefits**
    - The successful use of EV submetering via charging stations could reduce the cost of EV charging, however the costs savings—an average of $374 per installation—were modest at the time of the project as compared to installing a second utility-grade meter. At the same time, to scale submetering to customers across

California was estimated to cost the utilities from $3,215,000 to $5,000,000 per utility[53] at the time. This demonstration identified that third-party EV submetering solutions were not ready to be deployed to serve the state of California, and thus this project helped to avoid the substantial cost associated with the statewide rollout of such a solution at the time.

- **Adoption of EPIC Technology**
    - PG&E identified key elements of third-party EV submetering solutions that will need to be improved before they are deployed to serve the state of California.
    - The learnings from this project enabled a successor project with EPIC 3.27.
- **Support of CPUC Proceedings or State Requirements**
    - D.13-11-002 on utility requirements for the development of the Submetering Protocol
    - R.13-11-007 Alternative-Fueled Vehicles Programs

Project 1.23 - Demonstrate Additive Billing with Submetering for PVs to Increase Customer Billing Flexibility

This project focused on developing, testing, and validating a way of collecting or estimating solar generation output data and enabling a subset of customers to view their estimated solar generation data through integration with PG&E's YourAccount website. Upon determining that using estimated PV generation data would be a viable option, the project also assessed the accuracy of the algorithm used by a third-party vendor. The project determined that additional data is necessary to develop a scalable PV generation estimate, including shading impacts, PV system tilt and azimuth, as well as weather data like fog and marine layer.

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53. By identifying that third-party EV submeters were not ready to be deployed, this project helped avoid substantial cost of a statewide rollout between $3,215,000 to $5,000,000 (SME estimate).

Benefits

- **Reliability**
  - While the project identified limitations in the existing data quality, once resolved the estimated PV generation data identified in this technology demonstration project may help PG&E understand the changing base load characteristic resulting from increased PV generation. It may also provide planners with more detailed and accurate information to better understand the gross load to properly account for actual demand on specific assets. The data could also be useful for distribution operators to more accurately quantify load masking and generate more accurate predictions of expected PV generation for short term forecasting. This could potentially help improve the distribution planning process and energy procurement.
- **Economic Benefits**
  - The use of estimated generation is more cost effective than installing submeters for PV applications or paying for the data from a third-party solar provider. Customers can also have a better understanding of their individual PV systems with respect to their energy usage.
- **Environmental Benefits**
  - PV generation to customers allows them to understand the impact of their generation on their individual energy usage especially when combined with time of use metering and disaggregated load information. This could ultimately help customers be more efficient energy users.
- **Support of CPUC Proceedings or State Requirements**
  - R.14-08-013 Distribution Resources Plans
  - R.14-10-003 Integrated Distributed Energy Resources

Project 1.24 - Demonstrate Demand-Side Management (DSM) for Transmission and Distribution (T&D) Cost Reduction

This project successfully provided and tested the performance of a near real-time window of PG&E's Air Conditioning (AC) Direct Load Control (DLC) system, which utilizes one-way switch control devices. This allowed us to improve our ability to estimate AC DLC impacts at the distribution system level to better understand the localized impact of AC direct load control devices on meeting distribution feeder level reliability concerns. It also enabled near real-time visibility of AC direct load control installations to support Transmission and Distribution (T&D) Operations and provided Demand Response (DR) program administrators with near real-time feedback on any problems with direct load control devices before, during or after an event is called, which supports T&D operational improvements.

Benefits

- **Reliability**
    - Near real-time visibility into program performance advances a strategic objective to utilize DR resources not only to displace generation capacity, but also to support transmission and distribution grid reliability and improve performance of load control programs. This could be particularly important in the context of the increasing need to support renewables integration onto the distribution grid.
- **Economic Benefits**
    - The near real-time visibility and data collected by the data loggers can be used to reduce program operation costs and potentially reduce T&D infrastructure costs.
- **Adoption of EPIC Technology**
    - 586 data loggers were installed on or near the sampled outdoor A/C units in the project’s target area. After project completion, the SmartAC Program continued to use the deployed data loggers to actively monitor program impact.
- **Support of CPUC Proceedings or State Requirements**
    - A.12-07-004 Demand Response (DR) Incentives
    - A.14-06-001 Demand Response (DR) Change in Tariff Rules

- R.13-09-011 Demand Response (DR)

Project 1.25 - Develop a Tool to Map the Preferred Locations for DC Fast Charging, Based on Traffic Patterns and PG&E's Distribution System, to Address EV Drivers' Needs While Reducing the Impact on PG&E's Distribution Grid

This project addressed Electric Vehicle (EV) adoption barriers by identifying optimal locations within PG&E's territory for the placement of DCFCs based on factors such as cost, available service transformer capacity, traffic patterns, as well as site host and driver preference. PG&E worked with industry experts to identify the 300 locations of highest unmet public charging need, forecasted out to 2025. Using a variety of inputs, including publicly-available business listing data, PG&E's distribution network to assess available distribution capacity, results from expert interviews, and PlugShare's database on existing public charging locations, the team then identified over 14,000 individual potential charger host sites, such as businesses, parking lots, and public places. The results of the project were developed into an interactive online map that visualizes the 300 optimal DCFC locations. The publicly-available map is accompanied by guidelines in the final report surrounding best practices for siting DCFCs developed to further encourage EV adoption by drivers, site hosts, and developers.

Benefits

- **Reliability**
  - By providing recommended site locations based on available transformer capacity, PG&E guided developers to install DCFCs in locations that would mitigate capacity overload or upgrades.
- **Economic Benefits**
  - The report identified distribution upgrades as a major cost driver for DCFC installers. Identifying site hosts with and without distribution capacity, assists in

saving the time and money from potential installers by identifying site hosts that have available capacity.

- **Environmental Benefits**
  - This project developed capabilities to support the deployment of charging infrastructure, which furthers the overarching goal of clean transportation.
- **Adoption of EPIC Technology**
  - The tools developed in this project helped enable PG&E to engage with OEMs and state stakeholders to help facilitate planning and siting of DCFCs. In addition to posting the interactive map on its EPIC website, PG&E has sent the siting tool to over 30 different external stakeholders upon request since project completion.
- **Support of CPUC Proceedings or State Requirements**
  - R.13-11-007 Alternative-Fueled Vehicles Programs
  - R.18-12-006 Development of Rates and Infrastructure for Vehicle Electrification (DRIVE)

EPIC 2 Project Benefits

Project 2.02 - Distributed Energy Resource Management System

This project provided an opportunity for PG&E to define and deploy a DERMS and supporting technology to uncover barriers and specify requirements to prepare for the increasing challenges and opportunities of DERs at scale. The DERMS Demo was a ground-breaking field demonstration of optimal control of a portfolio of 3rd party aggregated behind-the-meter (BTM) solar and energy storage and utility front-of-the-meter (FTM) energy storage to provide distribution capacity and voltage support services while also allowing for participation of these same DERs in the CAISO wholesale market.

Benefits

- **Safety**

- Better visibility into DERs on the grid will give the utility more confidence that any switching operation on circuits with DERs accounts properly for the contributions of DERs, better preserving safety in situations where the grid is abnormally switched.

- **Reliability**
  - While significant problems were experienced by PG&E because of DERs are relatively infrequent today (e.g. masked load, capacity and voltage violations, reverse power flow), DER penetration is expected to increase in the future and DERMS technology could address the associated increase in issues related to the planning and operation of an increasingly complex distribution grid.
- **Economic Benefit**
  - DERMS technology may allow PG&E to avoid costly upgrades and plan the grid more efficiently. DERMS technology may also enable DERs to be more effectively used for wholesale market participation, unlocking additional value streams for customers and optimizations for front-of-the-meter resources.
- **Environmental Benefits**
  - The development and deployment of a DERMS platform will enable the continued integration of renewables into the grid.
- **Adoption of EPIC Technology**
  - This project informed numerous foundational requirements around DER monitoring and communication within PG&E's 2020 General Rate Case (GRC), CH 19: Integrated Grid Platform Program and Grid Modernization Plan, specifically for Advanced DMA Platform and SCADA Replacement and Distribution GIS Asset Data Improvement investments. The learnings from this project also contributed to PG&E's successful EPIC 3.03 – *Distributed Energy Resource Management System (DERMS) and Advanced Distribution Management System (ADMS) Advanced Functionality* project.
- **Technology Development Progress**

- Through collaboration with the participating vendors, other PG&E demonstrations, and industry leaders to successfully demonstrate the potential of DERMS technology and achieve key learnings, the DERMS demonstration progressed the state of the industry.

- **Support of CPUC Proceedings or State Requirements**
  - The findings from the project have been used to support changes to telemetry requirements for DER interconnections under Rule 21 (R.17-07-007), and informed PG&E's participation in Rule 21 Working Groups 3 and 4, and the Smart Inverter Working Group.
  - R.11-09-011 Rule 21, Smart Inverter
  - R.14-10-003 Integrated Distributed Energy Resources

Project 2.03A - Test Smart Inverter Enhanced Capabilities – Photovoltaics (PV)

This project field-demonstrated commercial Smart Inverters (SIs) on a high photovoltaic (PV)-penetration distribution feeder, evaluated a vendor-agnostic SI aggregation platform, and lab-tested multiple SI models. The project established that there is significant potential for cost-effective local voltage support from SIs to help mitigate local secondary voltage challenges caused by high PV penetration. The learnings from this project have directly contributed to an enhanced understanding of the potential of Smart Inverters, and are valuable for distribution grid operations, electric generation interconnection, distribution planning, and customer programs.

Benefits

- **Reliability**
  - In its current form, today's grid—especially its distribution system—was neither designed nor equipped to accommodate such a high penetration of DER while sustaining high levels of electric quality and reliability. This project demonstrated

SI capabilities to improve grid reliability by mitigating the impact of renewable resources on secondary and primary system voltage.

- **Economic Benefit**
    - Conventional mitigation measures (transformer upgrades, reconductoring, additional voltage regulation equipment, etc.) provide a possible path towards accommodating more distribution-connected DER in PG&E's service territory. CPUC Electric Rule 21 mandating the use of SIs with autonomous functions provides new, alternative solutions that may perform equally well with potential for improved ratepayer benefits. Specific 2.03A activities that targeted cost reductions included 1) the evaluation of SI ability to help mitigate voltage problems resulting from high PV penetration on a distribution feeder and 2) the modeling study, which performed an economic analysis of SI capability vs. traditional grid upgrades across multiple PG&E distribution feeders and evaluated the potential to update PG&E standards for performing voltage rise studies when new BTM DERs are interconnected.
- **Environmental Benefits**
    - SIs can help to better integrate renewables, and, therefore, advance California energy policy to increase the amounts of renewable and distributed generation on the grid. By assessing SIs' ability to address DER-caused voltage issues through both the field demonstration and modeling, this project shed light on SIs' potential to increase hosting capacity, potentially allowing for faster and more affordable interconnection of additional DERs onto PG&E's distribution system. Additionally, lab testing activities evaluated SI responses to extreme grid conditions, which may result in updates to SI standards.
- **Adoption of EPIC Technology**
    - Provided insights and lessons about how to improve operations for the 2020 GRC, Chapter 19: Grid Modernization, specifically for Advanced DMA Platform and SCADA Replacement investments on distribution planning, interconnection enhancements, ADMS requirements, customer program(s) related to smart

inverters, as well as policies and contractual agreements for customers to allow PG&E to use/control their smart inverters in the service of power quality.

- **Support of CPUC Proceedings or State Requirements**
    - The findings from the project were used to support changes to telemetry requirements for DER interconnections under Rule 21 (R.17-07-007), and informed PG&E's participation in Rule 21 Working Groups 3 and 4, and the Smart Inverter Working Group.
    - R.11-09-011 Rule 21, Smart Inverter
    - R.14-10-003 Integrated Distributed Energy Resources
- **Informed Industry and/or Company Standards**
    - Findings from the project were actively used to inform and Institute of Electrical and Electronics Engineers (IEEE) Smart Inverter standards.

Project 2.03B - Test Smart Inverter Enhanced Capabilities – Vehicle to Home

This project assessed the technical feasibility and potential benefits to individual customers and to ratepayers of vehicle to home (V2H) technology which can be utilized for resiliency and reliability. This project showed that at the time, V2H was technically capable of islanding and supporting household load in outage and demand response events and customers reported high initial interest. However, the technology was not yet commercially available and vehicle warranties would have needed to be modified to allow for discharge, the cost to customers exceeded their perceived benefits, and the net benefits to the utility and ratepayers were likely not sufficient to surmount the low cost-effectiveness for customers. The V2H market was nascent at the time of this project and required further investigation ahead of PG&E commercialization activities.

Benefits

- **Safety**

- The project contributed to this principle by exploring and documenting the interconnection requirements for V2H technology ahead of broader commercialization. B-directional power flow-capable EVs were not commercially available in the United Sates at the time. The project showed that for V2H technology to become a mass market product, the automotive manufacturers would need to build EVs with these capabilities. Documenting these requirements would help inform market actors' understanding of safety considerations while pursing commercialization of the technology.

- **Reliability**
  - The project contributed to this principle by demonstrating technical feasibility at a proof-of-concept level that methods could be available to load serving entities for leveraging EVs to support DR activities during peak load and outage conditions.
- **Economic Benefits**
  - The project contributed to this principle by demonstrating the technical feasibility of V2H and validating the costs and benefits of the V2H technology at a directional, site-specific level to vet the potential commercial prospects of the technology before dedicating ratepayer funds to support commercialization. As this project helped to identify that V2H technology was not yet commercially viable at the time, PG&E estimated this project helped to avoid what could have been up to a $5.8M incentive program to spur V2H adoption at the time of the project.
- **Environmental Benefits**
  - V2H could maximize a customer's existing renewable generation (PV) by paring it with EV and potentially storage. These non-fossil fuel-based power generation technologies can facilitate reducing GHG emissions by offsetting any fossil fuel-based generation on PG&E's system.
- **Technology Development Progress**

    - This project identified a set of key issues that needed to be addressed before V2H solutions could be commercialized.
- **Support of CPUC Proceedings or State Requirements**
    - R.18-12-006 Development of Rates and Infrastructure for Vehicle Electrification (DRIVE)
    - R.13-11-007 Alternative-Fueled Vehicles Programs
    - R.11-09-011 Rule 21, Smart Inverter

Project 2.04 - Distributed Generation Monitoring and Voltage Tracking

This project demonstrated an algorithmic process to analyze new data sources (including SmartMeter devices and databases of solar irradiance) to predict the likelihood that a Rule 2 voltage violation was caused by distributed solar generation. Solar energy is by nature intermittent, and ebbs and surges of generation can change the voltage for neighboring, downstream customers. As solar adoption continues to grow, there is an increased likelihood of such voltage violations. This functionality, if integrated into a larger grid analytics platform, might improve decision making for Power Quality Engineers responding to customer issues, and Distribution Planners as they work to support safe and reliable solar installation across PG&E's service territory.

Benefits

- **Reliability**
    - The results of this project can enable power quality, planning and operating engineers to better understand the likelihood that a voltage violation is caused by DG. For Power Quality, this potentially means faster response to customers. For Operating Engineers, this may save money by reducing the number of trouble man trips. For Planning Engineers, this may help make better DG siting decisions in the future.
- **Economic Benefits**

- The ability to identify the likelihood and location of voltage problems associated with PV installations has the potential to reduce the time and costs of investigating and resolving violations, because trips to the field to investigate the problem gather data and implement the final resolution are reduced. The predictive analysis may also have the potential to enable PG&E to anticipate and avoid future voltage violations related to DG.

- **Environmental Benefits**
  - Providing the ability identify the likelihood of whether PV installations will create voltage problems could identify areas capable of supporting additional PV installations. This supports PG&E's shifting energy procurement requirements towards renewable generation sources and reductions in GHG emissions.
- **Support of CPUC Proceedings or State Requirements**
  - R.14-08-013 Distribution Resources Plans

Project 2.05 - Inertia Response Emulation for DG Impact Improvement

As California pursues its objective of reducing carbon emissions of the power system, Pacific Gas and Electric Company (PG&E) is increasing the amounts of renewable generation in its generation resource mix. Conventional generation, such as gas fired plants, are machine-based, synchronous, rotating power generation resources and are being replaced by renewable generation, such as solar photovoltaic (PV) power plants and wind turbines, which are electronic and inverter-based resources. This generation technology shift decreases the total inertia of spinning mass connected to the grid, which is one property of the system that helps maintain stability during sudden disruptions, such as the loss of major generators. To compensate for future decreased inertia on the grid, this project investigated how to add "Synthetic Inertia" to maintain the reliability and robustness of a future renewable grid.

This project explored the capabilities of inverter-based energy resources to provide a set of functions related to system inertia which support the electric system. The project demonstrated via transmission system modeling and Power-Hardware-In-Loop testing that advanced inverter control methods can provide active power support that improves the system's frequency response in the face of reduced conventional inertia from synchronous machine generators. Inverter control methods were explored including inertia-like response (derivative control) and grid-forming (voltage source) modes for respective benefits in bulk system and isolated distribution system use cases.

Benefits

- **Reliability**
  - Transmission level modeling was created and used low-inertia scenarios to identify thresholds and conditions where system instability reaches a critical level. The threshold identified was an inverter-based penetration threshold of 57 percent. Before this project, the potential impact of inverter-based resources and low-inertia was virtually unknown.
- **Environmental Benefits**
  - Most renewable energy resources are inverter-based and this project enables more generation resources to interconnect to the grid. This will lower the GHG emissions, air pollution, and subsequent negative health impacts produced by the electricity sector.
- **Technology Development Progress**
  - The EPIC project team worked with a variety of stakeholders to share knowledge gained from this research including EPRI, WECC, NERC, NREL, and SCE.
  - In March 2019, NREL presented the findings on PG&E's behalf at the Energy Systems Integration Group (ESIG) meeting in regards to EPRI Program 173: Bulk System Integration of Renewables and Distributed Energy Resources.[54]
- **Adoption of EPIC Technology**
  - Provided insights and lessons about how to improve operations for 2020 GRC, Chapter 19: Grid Modernization, specifically for Electric Generation

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54. https://www.epri.com/research/programs/067417.

Interconnection investments. It will potentially revise PG&E's interconnection standards for storage, PV, or other inverter-based generation, enhancing the definition of how to safely and reliability integrate these technologies onto the system.

- **Support of CPUC Proceedings or State Requirements**
  - R.11-09-011 Rule 21, Smart Inverter
  - R.17-07-007 Streamlining Interconnection of Distributed Energy Resources and Improvements to Rule 21
- **Informed Industry and/or Company Standards**
  - Learnings from this project informed IEEE Standard 2800 - Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems[55]
  - The findings from this project and IEEE 2800 will likely inform PG&E interconnection standards in the future.

Project 2.07 - Real Time Loading Data for Distribution Operations and Planning

This project developed analytical methods for generating near real-time load forecast information. The project successfully built and demonstrated a platform to ingest and process SmartMeter, Supervisory Control and Data Acquisition (SCADA), photovoltaic system (PV) generation, Geographic Information System (GIS) and weather data for two of the eight Areas of Responsibility (AOR) within PG&E's service territory.

Benefits

- **Safety**

55. https://standards.ieee.org/ieee/2800/10453/.

- Having look ahead visibility into dynamic grid load conditions will allow operators to better plan for maintenance and enhance operational decision-making awareness.

- **Reliability**
    - Providing forecasted load visibility to distribution engineers and operators to allow them to manage distribution switching for both planned and unplanned events more quickly and with less switching steps.
- **Economic Benefits**
    - Having accurate predictive load forecasts may reduce the number of switching steps required to perform maintenance and restoration and therefore reduce operational costs.
- **Adoption of EPIC Technology**
    - Provided insights and lessons about how to improve operations for 2020 GRC, Chapter 19: Grid Modernization, specifically for Advanced DMA Platform and SCADA Replacement investments.

Project 2.10 - Emergency Preparedness Modeling

The project developed and demonstrated a decision support system that successfully recommends optimal restoration and resource allocation strategies for PG&E electric assets after a disruptive event occurs.

Benefits

- **Safety**
    - This application will allow resources to respond to public safety incidents more rapidly. Deploying the appropriate number of resources to an event will allow safety personnel to rapidly address hazards like a downed wire or leaning pole.
- **Reliability**
    - Reduced restoration times leading to a more reliable electrical service: Accurate resource allocation recommendations in advance of an event will ensure that

logistics will provide the right amount of support, while mutual aid or contractors can be activated and transported to the optimal locations. These decisions require lead time, so timely analysis or forecasts will eliminate any delays associated with acquisition or decisions that need to be made due to a faulty analysis.

  - Enhance reliability using real-time information: The Emergency Operations Center (EOC) would have the ability to explore restoration strategies using real-time information to enhance reliability of the electric and gas systems. This project could enable PG&E to better quantify, in real-time, the impacts of events and the impacts of different restoration activities taken on power outages and costs.
  - This project has the potential to achieve reliability benefits by increasing PG&E's ability to model natural hazards and outage restorations. The tool can be agnostic to type of emergency (earthquake, flood, fire, tsunami, major storm, etc.). Benefits are multiplied because the tool has the potential to handle any type of major catastrophic event, and scale accordingly to the importance of the event.
- **Economic Benefits**
  - The optimization of restoration plan development can reduce cost by recommending the most efficient allocation of resources.

Project 2.14 - Automatically Map Phasing Information

This project successfully developed and demonstrated automated analytical methods for determining meter phasing and meter-to-transformer connectivity using SmartMeter, Supervisory Control and Data Acquisition (SCADA) and Geographic Information System (GIS) data. The distribution network model is central to multiple existing control systems, system analyses, and work processes. As the load characteristics of the distribution network evolve, such as with the growth of Distributed Energy Resources (DER), it is becoming more important to have accurate and up-to-date network model information to be able to actively manage the distribution system. Automated approaches for obtaining this information can offer a more efficient alternative to the conventional boots-on-the-ground approach.

Benefits

- **Increase Safety**
  - Phase identification is required for detailed understanding of network topology and complex power flows introduced by increasing DERs, to ensure safe operation of the system.
- **Improve Reliability**
  - Instability and reliability issues can result if one phase is significantly different in load than the other two. This project enables PG&E to better balance the loading on the 3 phases of the power delivered.
- **Reduce Costs**
  - These automated solutions developed in this project, if deployed across PG&E's entire service territory, would potentially provide around $9,000,000 in avoided cost savings and reduced customer bills compared to a PG&E-wide conventional "boots on the ground" phase identification effort.[56]
- **Environmental Benefits**
  - Better Phase ID can help accommodate the interconnection of renewable DERs. These non-fossil fuel-based power generation technologies can facilitate GHG emissions reduction by offsetting fossil fuel-based generation on PG&E's system.

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56. In the absence of analytical phase identification methods, manually verifying phase information would likely need to be performed on the majority of circuits. Assuming 70 percent of circuits of PG&E's 2,500 circuits would need to be verified, at a cost of $7,000 per circuit, avoiding this by instead applying analytical methods would result in a cost savings of approximately $12M. The most successful analytical method demonstrated in 2.14, which would be used in production, was developed by PG&E within the EPIC project. However, to account for follow-on improvements made to the analytical method after the EPIC project and before operational deployment, a 75 percent attribution factor is applied, which results in $9M benefits attribution to EPIC 2.14.

- **Adoption of EPIC Technology**
    - The full-scale deployment of this project's solutions was included in PG&E's 2020 GRC, CH 19: Integrated Grid Platform Program and Grid Modernization Plan.
- **Support of CPUC Proceedings or State Requirements**
    - R.14-08-013 Distribution Resources Plans

Quantitative Benefits Summary

Benefit Area	Measurement
Economic Benefits	$9,000,000

Project 2.15 - Synchrophasor Applications for Generator Dynamic Model Validation

This project installed Phasor Measurement Units (PMUs) on the three generators at PG&E's Colusa Generation Station, developed station generator models using commercial software, and used actual disturbance data collected online (in lieu of offline test data) to test new synchrophasor applications for generator model validation. The integration of PMUs on generators for dynamic model validation is a new technology and the project did not result in a tool that is production ready. As applications evolve, installation of PMUs at generating stations could potentially allow utilities to enhance their generator model validation processes.

Benefits

- **Reliability**
    - The project demonstrated the use of synchrophasors and associated software tools to perform parameter estimation for generator dynamic models remotely using collected disturbance data. Current processes require testing at the power plant. More accurate generator models would result in more accurate grid reliability studies. The tool and methodology tested did not conclusively demonstrate that it could be replace current test methods based on the reasons covered in the final report.

- **Economic Benefits**
    - The collection and use of synchrophasor data, to perform NERC-mandated generator dynamic model calibration, potentially reduces the need to perform tests at the power plants. This could reduce costs and is an efficient use of ratepayer monies. As noted in the final report, the cost savings was not proven sufficient to justify the cost of installing generator PMUs.
- **Adoption of EPIC Technology**
    - Provided insights and lessons about how to improve operations for 2020 GRC, Chapter 4: Hydro Operations Costs.

Project 2.19 - Enable Distributed Demand-Side Strategies & Technologies

This project evaluated the performance and efficacy of using customer-sited behind-the-meter storage for grid and reliability services. The project utilized both residential and commercial assets via two vendor platforms. The project showed that BTM energy storage is technically feasible for the use cases evaluated, and also identified opportunities for improvement to inform broader application of these use cases.

Benefits

- **Reliability**
    - This project explored the use of customer-sited behind-the-meter storage to respond to instructions to charge during times of maximum solar output and discharge during the later afternoon net load ramp when solar output is declining, an application of the technology which could contribute to grid reliability. In addition, the project investigated the dual-use of customer-owned storage to provide back-up power for individual customers.
- **Economic Benefits**

- This project explored the use of customer-sited BTM energy storage to provide commercial customers with opportunities to lower their cost of energy via peak load shaving to avoid demand charges, while also executing directions to charge during times of maximum solar output and discharge during the later afternoon net load ramp when solar output is declining.

- **Environmental Benefits**
  - In addition to testing the ability of customer-sited storage systems to absorb system solar power, this project also explored the use of residential storage co-located with solar PV systems to charge the batteries exclusively using solar power. Both applications of customer-sited energy storage can help better integrate renewables.
- **Adoption of EPIC Technology**
  - Provided insights and lessons about how to improve operations for 2020 GRC, Chapter 19: Grid Modernization, specifically for Advanced DMA Platform and SCADA Replacement investments.
- **Support of CPUC Proceedings or State Requirements**
  - R.14-10-003 Integrated Distributed Energy Resources

Project 2.21 - Home Area Network (HAN) for Commercial Customers

This project demonstrated the viability and usefulness of access to real-time energy use data for commercial customers. This technology demonstration accomplished three set objectives: 1) verified Zigbee enabled SmartMeters for Large Commercial and Industrial customers have the same ability as residential meters to provide real-time usage information via the HAN radio; 2) Identified and assessed LC&I customers' needs and meaningful use cases (i.e. opportunities) for real-time data; 3) Identified the barriers to adoption, integration, and utilization of HAN devices at scale for LC&I customers.

Benefits

- **Economic Benefits**

- The project aimed to provide affordability benefits to customers by providing real-time AMI data to customer for Demand-Side Management (DSM). The technology presented in this project has the potential to offer an affordable option to maximize DSM if and when site installation requirements are met. Benefits will vary by customer. Some sites required modification or adaption to implement real-time data feeds, while other sites required a greater investment in time and resources to integrate the data into their EMS. The greatest benefits are likely to accrue where multiple locations are under a single EMS.

- **Environmental Benefits**
  - This project has shown real-time data directly enabled intervention actions related to quick PV system failure detection and recovery, and modification to DR strategy during DR event period. These interventions can lead to reduction in GHG gas emissions through lower energy usage and increase up-time of renewable energy resources.

Project 2.22 - Demand Reduction through Targeted Data Analytics

This project developed a tool that leverages customer level data along with grid information and forecasts to create a robust optimization engine for identification of the lowest cost solution capable of deferring or mitigating the need for an asset upgrade due to capacity limitations. The tool considers both traditional wires solutions and DER portfolios and allows Distribution Planners to complete advanced scenario analysis.

Benefits

- **Reliability**
  - The tool demonstrated in this project allows us to reduce the need to make equipment replacements and therefore reduce planned and unplanned outages.
- **Economic Benefits**
  - The tool developed in this project has the potential to significantly improve the efficiency and effectiveness of PG&E’s distribution planning process going

forward. The total annual benefit of the application of the optimization tool associated with 1) the identification and deferral of distribution capacity upgrades and 2) improvements in process efficiency.

- **Environmental Benefits**
    - The DER portfolios recommended by the tool demonstrated in this project reduce load requirements for the utility and therefore associated GHG emissions.
- **Adoption of EPIC Technology**
    - This project provided insights and lessons about how to improve operations for 2020 GRC, Chapter 19: Grid Modernization, specifically for Distribution Engineering Planning Tools investments and will be scaled up to support PG&E's advancing distribution planning processes through optimized location-specific targeting to leverage cost-effective, non-wires alternatives based on grid needs. The tool developed through this EPIC project has already been applied to the annual Distribution Deferral Opportunity Report (DDOR) and is expected to significantly improve the efficiency and effectiveness of PG&E's distribution planning process going forward.
- **Support of CPUC Proceedings or State Requirements**
    - R.14-08-013 Distribution Resources Plans
    - R.14-10-003 Integrated Distributed Energy Resources

Project 2.23 - Demand Side Utility Planning

This project successfully developed and demonstrated the integration of a broader range of customer-side technologies and Distributed Energy Resources (DER) approaches into the utility planning process. The project served as a necessary and enabling precursor to the fulfillment of Assembly Bill (AB) 327/ Section 769, which requires transparent, consistent and more accurate methods to cost-effectively integrate DERs into the distribution planning process. This project delivered new load shape profiles, enhanced load forecasting tool and overall analytical process that allows PG&E to more accurately and consistently integrate DER impact to the distribution system load profile. With these enhancements, PG&E can evaluate if DER growth could defer or even in some instances eliminate the need for future network upgrades. Leveraging any of the SmartMeter data, PG&E created more accurate and granular load shapes that allowed distribution planners to more precisely capture DER impact on the load growth forecast.

Benefits

- **Safety**
  - By hierarchically aggregating load shapes, PG&E engineers can leverage load forecasts to project the timeframe when power flow could reverse at certain distribution system components (e.g. voltage regulators, protective devices) that are not presently designed to operate under such conditions. The reverse power flow could create a safety concern, as equipment may be more likely to fail. With prior knowledge of such a condition possibly existing, PG&E planners could potentially address the problem and eliminate the safety concern.
- **Reliability**
  - The project leveraged SmartMeter data to generate more accurate load shapes and DER adjustment forecasts at the system and granular (customer) level. With more accurate representation of load and DER adoption, distribution engineers can better model current and future grid conditions. Consequently, the system simulation results will more accurately represent the direction and magnitude of power flows. Recommended infrastructure modifications, and equipment specifications and settings can therefore better match the actual conditions, improving the reliability of the system. This enhancement supports the ability to decrease overloads, of which wear on the system components inherently increases risk of outages.
- **Economic Benefits**
  - The ability to include DER adjustment forecast in an integrated least-cost planning framework will potentially result in lower system costs, by avoiding system upgrades where load growth will be offset with DER adoption. By having

the ability to analyze the DER profile impact on the overall load shape, PG&E will be able to potentially target certain DER programs that have the shape and magnitude appropriate to defer or eliminate network upgrades

- **Environmental Benefits**
  - This project can potentially reduce GHGs by helping to identify additional opportunities for distribution connected renewable generation.
- **Adoption of EPIC Technology**
  - This project provided insights and lessons about how to improve operations for 2020 GRC, Chapter 19: Grid Modernization, specifically for Distribution Engineering Planning Tools investments to ensure that DER forecasts are incorporated in PG&E’s planning process. The improved load forecasting capabilities developed in this project have been transitioned to operational use in support of the distribution planning process.
- **Support of CPUC Proceedings or State Requirements**
  - R.14-08-013 Distribution Resources Plans
  - R.14-10-003 Integrated Distributed Energy Resources

Project 2.26 - Customer and Distribution Automation Open Architecture Devices

PG&E's AMI Network is one of the largest private Internet Protocol Version 6 (IPv6) networks in the Unites States, with more than 5 million AMI devices connected across its electric network. This project investigated the use of the AMI network for purposes beyond the collection of electricity usage data. The project successfully demonstrated the ability of a Client-Server architecture consisting of an IoT router to establish communication, monitoring, command, and control of various third-party and utility end devices such as smart inverters, sensors, SCADA devices, RFID readers and distributed generation controls over the AMI network using the IEEE 2030.5 protocol.

Benefits

- **Reliability**
    - This project demonstrated the potential to use the AMI (mesh) network for communicating with SCADA and other electric distribution energy devices. A mesh network is more reliable than a non-mesh network because when one node is inoperable, other nodes can still communicate with each other directly or through intermediate nodes.
- **Economic Benefits**
    - The AMI-based RFID tracking capability for meter inventory management and asset identification showed the potential to reduce inventory costs.
- **Adoption of EPIC Technology**
    - The AMI-based RFID tracking capability for meter inventory management and asset identification has been funded through the GRC and is planned to be deployed.

Project 2.27 - Next Generation Integrated Smart Grid Network Management

This project demonstrated a new AMI Network management system (a "manager of managers") to holistically and more effectively monitor, control, and evolve the existing AMI network and infrastructure. Currently, PG&E leverages multiple AMI networks with separate operational systems. Leveraging disparate systems limits the ability to optimally manage workflow and prioritize and schedule data processes (for instance, ensuring remote connect/disconnect is prioritized over tenant application queries).

Benefits

- **Safety**
    - The automation of processes demonstrated through this project to identify and notify technicians of potentially hazardous conditions related to meter

temperature, incorrect meter-wiring, or energy diversion could allow for these conditions to be identified sooner and resolved faster than is possible through current manual processes.

- **Reliability**
  - The aggregation of data across PG&E's three AMI networks into a single management platform contributes to overall SmartMeter network reliability by providing, on a real-time basis, a high-level view of identified problems and then allowing for a quick drill down for evaluation and when appropriate, automatically generating and tracking follow-up work orders. Reliability of the SmartMeter network contributes to overall grid reliability by providing visibility to problems and enablement of troubleshooting in real time.
- **Economic Benefits**
  - The more efficient diagnosis of problems through process automation demonstrated through this project has the potential to reduce labor costs. This project demonstrated the ability to quickly narrow the problem area to provide improved information on when and what type of personnel to dispatch to resolve an issue. In addition, by quickly resolving issues such as high temperature sockets, equipment damage and replacement can be avoided.
- **Adoption of EPIC Technology**
  - Provided insights and lessons about how to improve operations for 2020 GRC, Chapter 8: Information Technology.

Project 2.28 - Smart Grid Communications Path Monitoring

This project sought to 1) Conduct an initial noise assessment to establish a baseline of radio frequency interference (RFI) in the AMI Networks, 2) Analyze a continuous flow of data to identify potential locations and sources of RFI, and 3) Develop an end-to-end process/tool from monitoring to mitigation of interference. PG&E identified through a sample of radio frequency (RF) data that there are potential channel congestion issues that can lead to RFI conflicts in the

AMI networks, however no specific RF tools existed to identify RFI signal(s) in PG&E's local Neighborhood Area Network (NAN). Given the RF dataset availability and access limitations, there was no feasible path to demonstrate a successful algorithm-based application for proactive automated interference detection. The preliminary work completed on this project could be leveraged in the development and/or use of future tools and in formulation of strategies around broader prevention of PG&E's network RFI.

Benefits

- **Economic Benefits**
    - Given the significant data access limitations encountered early in this project, there was no feasible path forward for the project team to demonstrate a successful algorithm-based application for proactive automated interference detection. Although a small sample of channel loading data was obtained for a small test area in San Francisco, the lack of continuous data points and resolution of this information restricted algorithm development and the ability to execute a complete end-to-end RFI solution. As such, PG&E made an early decision to discontinue the project and avoid any unnecessary further expenditures towards the project.

Project 2.29 - Mobile Meter Applications

This project designed, built, and tested the Next Generation Meter (NGM). This electricity meter was demonstrated to be the first revenue grade, high-resolution real-time power meter that fully met national standards for metering including ANSI C12.1 and ANSI C12.20 (accuracy), ANSI C12.19 (meter data table format) and C12.22 (cellular communication protocol format). The NGM was developed with a compact, modular design that takes advantage of a host of new technologies including faster microprocessors, expanded memory, and multiple communications pathways—all contained in a hardware package that is the size of a credit card. The NGM has the ability to: 1) Be installed in a wider range of locations beyond traditional customer premises, 2) Reduce meter maintenance and replacements costs, 3) Improve the grid operator’s situational awareness during outages, and 4) Provide additional services and applications as grid-edge technology evolves.

Benefits

- **Safety**
    - The design of NGM separates high and low voltage metering components of a SmartMeter. This separation reduces the exposure of field technicians to high voltages during maintenance and repair of meters.
- **Economic Benefits**
    - The design of the NGM modularizes meter components by separating high and low voltage components, which can significantly reduce both maintenance and operating costs. This provides the flexibility to replace only failed components, as opposed to the entire meter when one component fails.
- **Environmental Benefits**
    - The NGM will have the capability to consolidate metering of EV’s energy usage/charges at public locations/stations, or at home. This will enhance EV ownership and encourage the use of low-emission vehicles.
- **Adoption of EPIC Technology**
    - This project is the predecessor to EPIC 3.27, which is developing a revenue-grade EV submeter, in support of several proceedings.
- **Support of CPUC Proceedings or State Requirements**
    - R.14-08-013 Distribution Resources Plan
    - R.09-08-009 Alternative-Fueled Vehicle
    - R.13-11-007 Alternative-Fueled Vehicles Programs
    - R.18-12-006 Vehicle Electrification Rates and Infrastructure
    - CPUC Draft Transportation Electrification Framework

Project 2.34 - Predictive Risk Identification with Radio Frequency (RF) Added to Line Sensors

This project investigated the use of radio frequency-based Distribution Reliability Line Monitor (DRLM) and Early Fault Detection (EFD) technologies and compared their performance with Distribution Fault Anticipation (DFA) technology for predictive maintenance and risk reduction on electric distribution circuits. The demonstration successfully detected, located, and addressed multiple examples of conductor damage, vegetative encroachment, internal transformer discharge, fault induced conductor slap, and insulator and clamp issues. The project concluded that effective grid asset health and performance monitoring can be achieved through an ensemble approach and further work is necessary to improve and integrate sensor technologies into an analytics platform or Distribution Management System (DMS).

Benefits

- **Safety**
  - EFD's RF network monitoring offers to reduce the rate of occurrence of many classes of network faults that are known wildfire risks in California and globally. The technology predicts powerline fire risks ranging from vegetation encroachment to conductor (and conductor clamp) failure. Its predictive identification of risks allows them to be addressed proactively before they materialize.
- **Reliability**
  - EFD offers to reduce the number of network faults caused by deteriorated, damaged and compromised electricity network assets. The risks predictively identified in the demonstration were all known to be common causes of faults on PG&E's electricity distribution and transmission networks - faults that can and do regularly lead to interruptions to customer supply. Early warning of these risks can prevent the associated supply interruptions, thereby increasing supply reliability.
- **Economic Benefits**

- Cost savings associated with the deployment of EFD will result from the difference between repair to deteriorating or damaged equipment under normal schedule operating conditions instead of emergency conditions. If hazardous asset conditions are allowed develop to faults and asset failure, there is additional damage to asset infrastructure through the wear and tear of faults, as well as collateral damage to equipment near the fault, and greater labor costs to address these situations. Additional operational performance savings, such as reduction in system losses, would be achieved through the validation of correct operations of field equipment. Deployment of the EFD sensors demonstrated through this project on 75 additional feeders is now underway and is estimated result in around $6,000,000[57] in annual savings attributed to this EPIC project through reduced operating costs.

- **Adoption of EPIC Technology**
  - The EFD sensors from this project were transitioned to production at the project's limited demonstration sites, and a broader effort is underway to deploy EFD to 75 additional distribution circuits in high fire threat districts using GRC funds.
- **Technology Development Progress**

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57. Calculation assumes a total of $160,000 of reduced operating costs per feeder per year. This savings is attributed to 1) Reduced overtime and double-time maintenance ($40,000), 2) Reduced DCC mobilization ($20,000), 3) Reduced lost workdays due to rest periods ($25,000), 4) Reduced collateral facility damage ($50,000), and 5) Reduced customer claims ($25,000). The technology will be deployed on a total of 75 feeders over the next four years. Multiplying $160,000 savings/feeder/year by 75 feeders results in savings of $12,000,000/year at full deployment. While this EFD technology would likely not have been adopted had it not been demonstrated through EPIC first, it was already deployed at a limited scale outside the United States, and as such, 50 percent of the expected annual benefits to PG&E are attributed to the EPIC project. Applying the attribution factor results in a savings of $6,000,000/year attributed to EPICI 2.34.

  - Through course of the demonstration, the project team gave the vendors of the technologies being demonstrated extensive feedback that is being incorporated into improved versions of their sensor solutions.
- **Support of CPUC Proceedings or State Requirements**
  - R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans

Quantitative Benefits Summary

Benefit Area	Measurement
Economic Benefits	$6,000,000/year

Project 2.36 - Dynamic Rate Design Tool

This project designed and developed a tool that leverages advanced technologies to allow for the rapid evaluation of rate designs, new billing determinants, and enables a more robust, powerful, and rapid bill impact analysis process than the current models allow.

Benefits

- **Economic Benefits**
  - Using the rate design tool would enable employees to run analyses faster. The tool would enable employees to be more efficient and focus more on innovative rate design and evaluation.
- **Environmental Benefits**
  - Using the rate design tool developed through this project would lead to a reduction in errors in the rate design and evaluation processes by eliminating manual transfer of inputs and outputs.

EPIC 3 Project Benefits

Project 3.03 - Distributed Energy Resource Management System (DERMS) and Advanced Distribution Management System (ADMS) Advanced Functionality

This project has developed the foundation of a scalable enterprise distributed energy resource management system (DERMS) platform that can communicate with non-SCADA distributed energy resources (DERs) and manage distribution needs and constraints to safely, reliably, and cost-effectively incorporate DERs into distribution grid operations. The primary deliverable of this project has been the establishment of a production-ready cybersecure DER head-end platform in IEEE 2030.5 communications standards to allow for customers to cost-effectively send telemetry data from their DERs back to PG&E. The development of this head-end system provides an effective means for customers with DERs over 1MW to comply with CPUC telemetry requirements established in Resolution E-5038, and provides the foundation for more advanced future DERMS coordination and control capabilities for a wide range of use cases.

Benefits

- **Safety**
  - Improves the safety of operating DERs by allowing distribution operators enhanced situational awareness for DERs that are supporting the grid.
- **Reliability**
  - Enables the ability to dispatch registration data requests to verify compliance of Smart Inverters (SI) with Rule 21 and monitor SI-based DERs to maintain safe and reliable grid operations.
  - Providing distribution operators enhanced situational awareness of DERs will help PG&E manage demand and capacity and avoid outages.
- **Economic Benefits**

- The CPUC now requires that all customers with DERs over 1MW provide telemetry data back to PG&E. The low-cost telemetry solution developed through this project has been transitioned into a production state with customers already being connected. It is conservatively estimated to save customers a total of $2,250,000/year[58] by providing them an alternative to using a recloser or mini-RTU to meet the telemetry requirement.

- **Adoption of EPIC Technology**
  - Per the commitment made through the Smart Inverter Working Group, the low-cost telemetry developed and demonstrated through this EPIC project has been transitioned into production in June of 2022, and four customers have already been connected
- **Support of CPUC Proceedings or State Requirements**
  - R.14-08-013 Distribution Resources Plan
  - R.14-10-003 Integrated Distributed Energy Resources
  - R.16-02-007 Integrated Resource Plan
  - R.11-09-011 Rule 21, Smart Inverter
  - R.17-07-007 Streamlining Interconnection of DERs and Improvements to Rule 21
  - R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans R.19-09-009 Microgrids Pursuant to Senate Bill 1339 and Resiliency Strategies
- **Informed Industry and/or Company Standards**
  - As PG&E continues to gain experience and lessons learned through the development of the DERMS EPIC 3.03 project, PG&E will work to address any

58. It is estimated that each customer will save approximately $90,000 by using PG&E's system instead of the alternative of using a recloser or mini-RTU, and that approximately 25 customers per year will connect and provide telemetry through PG&E's head-end system. It is further assumed that these benefits are 100 percent attributed to the EPIC 3.03 project, as it is unlikely that the market would have provided a viable solution had it not been for this EPIC project, and the output of the project is a system that has been transitioned directly into production. Total resulting customer savings attributed to EPIC 3.03 is $2,250,000/year.

gaps found in CSIP, IEEE 2030.5, Sunspec, and relevant cybersecurity standards via collaboration with the Smart Inverter Working Group, other CA Utilities, industry, and standards bodies.

Quantitative Benefits Summary

Benefit Area	Measurement
Economic Benefits	$2,250,000/year

Project 3.11 - Multi-Customer Microgrid for Enhanced Reliability & Resilience: Arcata-Eureka Airport

Through this project, PG&E worked with several partners, including the CEC, to establish the first multi-customer microgrid in PG&E's service territory at the Arcata-Eureka airport, and configure the local microgrid controller to integrate with PG&E's distribution network and enable Distribution Control Center visibility and control of the microgrid. The project developed scalable and replicable approaches to planning, designing, deploying, and operating multi-customer microgrids that will be essential to enabling the broader implementation of multi-customer microgrids going forward. The project also helped to inform the CPUC's microgrid proceeding, and defined the tariff structure and interconnection process of PG&E's broader Community Microgrid Enablement Program (CMEP).

Benefits

- **Safety**
    - EPIC 3.11 helped PG&E establish protocols for linemen safety and informed how they should interact with microgrids. Safety materials such as bulletins, job aids, and training for distribution operators were created.
    - The project team is using the lessons to develop a microgrid island study which will analyze the performance and operational safety of a microgrid.
    - Public safety benefits from this project as it ensures critical facilities remain energized. These critical facilities are the Redwood Coast Airport which supports

Life Flight which supports organ donation as well as the US Coast Guard which has saved dozens of lives in the past year.

- **Reliability**
  - This project enhances resilience and prevents outages due to PSPS, EPSS, car poles, end of the line, tsunami, fire, etc. The Arcata RCAM microgrid was specifically proposed due to tsunami risk and the learnings at RCAM have helped PG&E understand how to implement microgrids to other areas of the grid where outages from other causes are more common.
  - Two reliability microgrid programs have been heavily influenced by the Arcata RCAM project: the Community Microgrid Enablement Program (CMEP) and the Microgrid Incentive Program (MIP). After four years, these programs will likely result in a dozen microgrids, and this will result in an estimated reliability improvement of 160,000 CMI per year.[59]
- **Economic Benefits**
  - After four years of CMEP and MIP program implementation, the economic benefits due to the reduced outage time is estimated to be $3.9 million per year going forward.[60]
- **Environmental Benefits**
  - The addition of solar and battery energy storage systems in the microgrid will reduce the use of diesel generators during power outages.
- **Technology Development Progress**

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59. Assuming 12 microgrids are built over the next four years, a microgrid uptime during outage of 95 percent, 20 non-residential customers per microgrid, and an average annual outage minutes per customer of 1,298 (from the worst performing circuits), and a 50 percent benefits attribution to EPIC 3.11, this results in a reduction of 160,000 CMI per year attributed to EPIC 3.11.

60. This assumes the previously calculated reliability benefits of 160,000 CMI per year are applied to a non-residential outage multiplier of $25.10 per customer-minute. This value is from the ICE calculator (https://icecalculator.com/home) with only non-residential customers added to the inputs.

- The Redwood Coast Airport Microgrid has served as a model for the deployment of other microgrids in the state of California and beyond, helping to establish hardware, software, communications, and tariffs requirements. The project has directly informed the design of PG&E’s CMEP and MIP programs.
- The project team worked with vendors to establish control schemes which allows PG&E's microgrid controller and the generation controller to interact and work together. To PG&E’s knowledge, this has not been done before and the controls manufacturer had not done this before, so this informed the manufacturer’s approach to implementing this technology.
- The project team influenced the vendor’s battery system. PG&E saw a difference from the stated battery specifications and what was observed in the lab testing. This was brough to the battery vendor’s attention and the specification was changed to reflect the lab testing results.

- **Support of CPUC Proceedings or State Requirements**
  - R.14-08-013 Distribution Resources Plan
  - R.11-10-023 Distribution Resource Adequacy
  - R.14-10-003 Integrated Distributed Energy Resources
  - R.16-02-007 Integrated Resource Plan
  - R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans R.19-09-009 Microgrids Pursuant to Senate Bill 1339 and Resiliency Strategies
  - R.15-03-011 Energy Storage Procurement Program
- **Informed Industry and/or Company Standards**
  - This project will inform the microgrid island study template which is under development.
  - The project helped define a microgrid architecture that works with PG&E policy and the technical capabilities that currently exist. Before this project, microgrids like this would have conflicted with company policy. This project will pioneer industry standards for replicable processes for the provisioning of local multi-

customer microgrid controllers, and for the communication and controls between those controllers and the larger grid.
    - The project informed a set of guidelines that equipment must meet in order to be a part of the community microgrid. There are currently a set of requirements for now, and although there are no standards yet, these requirements will likely become standards in the future.
    - This project directly informed the tariff structure and interconnection process of PG&E's CMEP.

Quantitative Benefits Summary

Benefit Area	Measurement
Increased Reliability	160,000 CMI/year avoided
Economic Benefits	$3,900,000/year

Project 3.11B - Location-Specific Options for Reliability and/or Resilience Upgrades

This project is in its early stages and will investigate if behind-the-meter (BTM) DERs can reduce the environmental and customer impacts of Public Safety Power Shutoff (PSPS) by being accommodated (not curtailed), enabled and/or relied on in microgrids. Using BTM DERs owned by third parties, combined with utility owned generation, and battery resources, this technology has the potential to reduce the outage time and diesel generation emissions related to PSPS.

Benefits

- **Safety**
    - This project will ensure that BTM DERs can operate safely during PSPS events.
- **Reliability**
    - This project reduces the impact of PSPS events on customer's energy access.
- **Economic Benefits**

    - During PSPS events, this project would save on diesel costs for backup generation as well as avoiding economic costs due to an outage.
- **Support of CPUC Proceedings or State Requirements**
    - Senate Bill 1339 and the CPUC Microgrid Order Instituting Rulemaking (OIR)

Project 3.13 - Overhead Transformer Monitoring

This project will install and test pre-commercial overhead transformer temperature sensors on operational transformers in the field. Temperature data, and other available telemetry data, will be manually downloaded from the third-party vendor's server. The project will develop analytical models for analyzing temperature data, with other available data elements, such as load data and weather data. The objective of the data model will be to predict incipient/impending transformer failure.

Benefits

- **Safety**
    - Certain transformer failures can cause customer outages and potentially even fires. This project will allow for more proactive identification and mitigation of these risks.
    - Eliminating catastrophic failure limits possibility of Serious Injury/Fatality (SIF) Incidents, Notice of Violations (NOVs) and corresponding resources that need to be allocated to SIF and NOV cases.
- **Economic Benefits**
    - Proactively addressing issues allows for straight time charging vs. overtime charging. Enables estimating teams and field crews to perform planned work procedures (such as pole loading calculations and sizing the transformer for peak load conditions) rather than performing emergency, unplanned work and installing like-for-like size transformers in emergency situations.
- **Support of CPUC Proceedings or State Requirements**

- R.08-11-005 Decision adopting regulations to reduce fire hazards associated with overhead electric utility facilities and aerial communications facilities
- R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans Pursuant to Senate Bill 901 (2018)

Project 3.15 - Proactive Wires Down Mitigation - Rapid Earth Fault Current Limiter (REFCL)

This project is demonstrating Rapid Earth Fault Current Limiter (REFCL) technology at a PG&E substation serving a high fire-risk area, to assess its effectiveness at automatic current reduction in wires-down events, with the goal of drastically reducing the likelihood of wires down events causing wildfires.

Benefits

- **Safety**
  - Over the course of this demonstration, this promising REFCL solution has met or exceeded performance metrics for how fast it reduces current during faults and has the potential to reduce the number of ignitions from wires-down events on the 12kV distribution circuits in PG&E's High Fire Threat Districts by over 59 percent.
- **Reliability**
  - REFCL could improve reliability over the operating practice of proactively de-energizing circuits during high fire risk events. This project could also improve reliability by riding through transient faults.
- **Economic Benefit**
  - Using REFCL to reduce the likelihood of ignition in turn reduces the likelihood of catastrophic wildfires and the associated financial impacts of those fires.
- **Technology Development Progress**

- PG&E has worked with the vendors that provide REFCL technology components to configure their product offerings for deployment on United States power grids, as previously REFCL has only been deployed by utilities overseas.

- **Adoption of EPIC Technology**
  - Pending successful completion of the demonstration, broader deployment of the REFCL solution is planned for additional substations in high fire thread districts through the GRC.
- **Support of CPUC Proceedings or State Requirements**
  - R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans
- **Informed Industry and/or Company Standards**
  - This demonstration will inform the deployment of other REFCL systems on California's electric grid, standardizing requirements for design, construction, and performance.

Quantitative Benefits Summary

Benefit Area	Measurement
Safety	59 percent[61] reduction in ignitions

Project 3.20 - Data Analytics for Predictive Maintenance

The core objective of EPIC 3.20 was to determine if machine learning models can be developed using existing utility data sets (such as AMI i.e. smart meters, asset location, and or weather data) to predict electric distribution equipment failures and outages, so that corrective action

61. The project has the potential of reducing the risk of electrical ignition events by 59 percent (based on statistics of fault type for electrical ignition events from February 2013 to April 2018). Calculation performed by PG&E's Applied Technical Services group and documented in the EPIC 3.15 - *Proactive Wires Down Mitigation - Rapid Earth Fault Current Limiter (REFCL)* business plan.

can be taken before either occurs. The project aimed to improve system reliability and safety by reducing unplanned outages by proactively identifying and mitigating equipment failure.

The project developed an industry leading analytical model for predicting issues with distribution transformers. Over 270 model predictions have been made so far, from which 62 percent were confirmed to be relevant transformer anomalies (a prediction success) and were flagged for field investigation. An additional 27 percent were confirmed to be other legitimate issues in the distribution system. On multiple occasions, near failing distribution transformers and meters have already been proactively replaced based on the model's recommendations.

Benefits

- **Safety**
  - Prediction of equipment requiring maintenance may potentially reduce public exposure to hazardous catastrophic equipment failure and reduce wildfire risk.
- **Reliability**
  - Predictive equipment maintenance reduces unscheduled outages caused by failed equipment. It is estimated that the technology prevents unscheduled outages by 1.2 million CMI per year.[62]
- **Economic Benefits**
  - Predicting that line equipment will require maintenance means that maintenance can be scheduled within normal operating workflow and avoid expensive unscheduled maintenance. Permitting targeted inspections as

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62. The reliability benefits assumes 100 interventions annually going forward (SME estimate), 13,274 customer outage minutes per distribution transformer failure (PG&E ILIS outage info), and that 90 percent of the interventions would eventually lead to transformer failure and an unscheduled outage and not been detected and prevented by other means. This results in a reduction of customer minutes of interruption of 1.2 million customer-minutes per year. The calculation further assumes an attribution of 100 percent to the EPIC 3.20 project because the transformer model was built from the ground up within the EPIC project, no comparable products are offered by vendors, and the tool has been transitioned directly into post-EPIC operation.

opposed to periodic inspections will better optimize field resources. Improved equipment operation will help optimize system performance.
  - The reliability benefits of 1.2 million CMI per year results in an economic benefit to customers of $3.2M per year.[63]

- **Technology Development Progress**
  - The overarching data science techniques are planned to be shared with the industry to enable broader market innovation around data-driven prediction of asset failure and maintenance needs.
- **Adoption of EPIC Technology**
  - Upon successful demonstration the software tool has been transitioned to continued use in production.
- **Support of CPUC Proceedings or State Requirements**
  - R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans

Quantitative Benefits Summary

Benefit Area	Measurement
Reliability	1.2 million CMI/year avoided
Economic Benefits	$3,200,000/year

Project 3.27 - Multi-Purpose Meter

This project leveraged the Next Generation Meter (NGM) developed in EPIC 2.29 to develop a utility-grade electric vehicle and EV charging submeter prototype that can be easily plugged into readily available level 2 and emerging level 3 EV charge stations. PG&E, the other California Utilities and industry influencers will update the EV submetering standard for CPUC adoption.

63. Using the CMI previously calculated as 1.2 million CMI per year and assuming a multiplier of $2.69 per customer-minute, the cost reduction is $3.2 million per year.

Benefits

- **Safety**
  - The separation of high and low voltage components enables the NGM core to be incorporated into EV chargers for easy and safe installation without exposure to high voltage hazards.
- **Reliability**
  - This EV meter will allow for non-traditional meter installations to obtain granular data (voltage, current, temperature, etc.) which enables monitoring capability and visibility.
- **Economic Benefits**
  - Reduced meter asset material and labor installation costs would demonstrate affordability and better use of rate-payer monies.
- **Adoption of EPIC Technology**
  - A limited set of submeters has been developed and demonstrated at PG&E facilities as part of this EPIC project. Broader piloting may be conducted within PG&E's service territory as follow up to the EPIC project. If successful, additional funding in support of broader scale deployment may be requested through the GRC.
- **Support of CPUC Proceedings or State Requirements**
  - R.14-08-013 Distribution Resources Plan
  - R.09-08-009 Alternative-Fueled Vehicle
  - R.13-11-007 Alternative-Fueled Vehicles Programs
  - R.18-12-006 Vehicle Electrification Rates and Infrastructure
  - CPUC Draft Transportation Electrification Framework
- **Informed Industry and/or Company Standards**
  - The design changes made to the EV charge stations by integrating the NGM will be reflected in EV submetering standards.

Project 3.32 - System Harmonics for Power Quality Investigation

This project is demonstrating the use of modern SmartMeters to detect, investigate and mitigate harmonic issues on the distribution system. Harmonics issues on the grid negatively impact customer equipment operation and can also damage utility assets.

Benefits

- **Reliability**
  - The current process for identifying and responding to harmonics issues is reactive and manual. Having real time access to harmonics data will help shorten the investigation time and resolution of customer power quality issue which results in reduction of customer equipment downtime.
- **Economic Benefits**
  - Harmonics data from next generation metering technology will reduce labor hours and operational costs associated with power quality investigation due to harmonics issues. Successfully resolving harmonics issues for customers will also prevent customer loss of potential revenue due to equipment downtime.
- **Adoption of EPIC Technology**
  - Through the EPIC project, modern SmartMeters capable of capturing harmonics data have been deployed to a limited number of sites in areas with high harmonics issues, to support the completion of the demonstration. Early results have been very encouraging, and if the demonstration is successful, broader deployment across PG&E's service territory will be conducted using GRC funds.
- **Technology Development Progress**
  - Currently, not all AMI meters have harmonics capability. If the project is proven successful, more meter vendors may consider adding harmonics capability to their product offerings to utilities.
- **Support of CPUC Proceedings or State Requirements**
  - R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans

- **Informed Industry and/or Company Standards**
    - The project relies on the industry standard for harmonics (IEEE 519). The results of 3.32 which is using harmonics data from AMI meters may be shared with the IEEE 519 working group at the IEEE annual conference and other power quality organizations such as CEATI.

Project 3.41 - Drone Enablement

This project is demonstrating the feasibility and value of advanced drone operations for two important PG&E use cases. The first use case is exploring automated and Beyond Visual Line-of-Sight (BVLOS) drone operations to collect imagery needed for the routine inspection of complex, high-voltage transmission structures. The second use case is exploring automated and BVLOS dispatch of drones from PG&E substations to investigate alerts generated by distribution system sensors, such as those being demonstrated by PG&E's EPIC 2.34.

Benefits

- **Safety**
    - PG&E currently flies drones manually within visual Line-of-Sight (LOS) to capture the extensive sets of images used to inspect these structures. Automating drone flights and extending BVLOS has the potential to offer a highly safe, repeatable, and efficient process that will significantly improve upon the manual approach employed today. As sensor-based alerting systems are deployed more broadly within High Fire Threat Districts (HFTD), dispatching drones as the first line of investigation for potential asset issues could provide a safer solution compared to the current approach of sending crews in trucks to investigate every qualified event.
- **Reliability**
    - The automated dispatch of drones to investigate analytically-triggered alerts of potential asset issues could enable faster and improved verification of potential issues, and improved resolution of issues before assets fail and outages occur.

- **Economic Benefits**
  - Automating drone operations, extending drone operations beyond visual LOS, and sending drones to conduct preliminary investigations instead of crews in trucks or helicopters has the potential to result in significant reductions in operating costs. Imagery captured by drones will contribute to a robust foundation of data, enabling continued advancements in machine learning applications such as automated image classification, which will reduce the need for manual image review.
- **Adoption of EPIC Technology**
  - Each of the project's two use cases are being conducted at a limited geographic scale within PG&E's service territory. If successful, broader deployment to the transmission lines, substations and distribution circuits within PG&E's High Fire Threat Districts will be requested through the GRC.
- **Technology Development Progress**
  - This project is already informing significant enhancements to two drone vendor solution offerings, to better support utility needs. If successful, the project will also inform additional viable pathways for securing FAA approval for BVLOS operations in support of PG&E use cases that will also be applicable to other utilities.
- **Support of CPUC Proceedings or State Requirements**
  - R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans
- **Informed Industry and/or Company Standards**
  - This project has involved coordination with the FAA on the development and hopefully future approval of a Part 107 waiver application, to enable drone operations for PG&E's two use cases. This could help pave the way for other utilities subsequently requesting FAA approval for similar use cases.

Project 3.43 - Predictive Maintenance Leveraging SmartMeter Blinks

This project is leveraging multiple sources of data, including but not limited to SmartMeter, time of day, location, and weather data, to proactively identify potential problems in the Electric Distribution system, specifically related to identifying locations with high incidences of momentary outages which may be caused by imminent failures of conductors, insulators, transformers and/or vegetation contact.

Benefits

- **Safety**
    - Prediction of equipment requiring maintenance may potentially reduce public and employee exposure to hazardous catastrophic equipment failure.
- **Reliability**
    - Predictive equipment maintenance may potentially reduce unscheduled outages caused by failed equipment.
- **Economic Benefit**
    - Predicting that line equipment will require maintenance means that maintenance can be scheduled within normal operating workflow and avoid expensive unscheduled maintenance. Permitting targeted inspections as opposed to periodic inspections will better optimize field resources. Improved equipment operation will help optimize system performance
- **Support of CPUC Proceedings or State Requirements**
    - R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans
- **Adoption of EPIC Technology**
    - Upon successful demonstration the capabilities developed in this project will be transitioned to production and may require additional enhancements and broader scale rollout using GRC funds. The insights from this project may also help to inform broader GRC requests.

Project 3.44 - Advanced Transformer Protection

This project will demonstrate and evaluate a novel protective relay for large substation transformers using negative-sequence transformer differential protection. This novel protection method would provide high sensitivity fault detection to detect internal winding faults. When left undetected over long periods of time, low-magnitude turn-to-turn faults can develop into a more severe fault that can cause a catastrophic transformer failure. This failure can result in a hazardous Boiling Liquid Expanding Vapor Explosion (BLEVE) and would also take a large and expensive asset out of service unexpectedly.

Benefits

- **Safety**
    - The novel protective relay would eliminate catastrophic failures of substation transformer due to low-magnitude internal turn-to-turn faults.
    - This project would prevent catastrophic transformer failures like Boiling Liquid Expanding Vapor Explosions (BLEVE) from occurring.
- **Reliability**
    - Advanced transformer protection will reduce the number of unplanned outages associated with internal turn-to-turn faults.
- **Economic Benefits**
    - This project would closely monitor the health of substation transformers while in operation. If accelerated transformer failure was detected, this could be repaired before it gets worse and causes failure before the transformer’s useful life.
- **Support of CPUC Proceedings or State Requirements**
    - PUC § 8360-8369: CA Grid Modernization Policy[64]

64. https://california.public.law/codes/ca_pub_util_code_div_4.1_chap_4.

Project 3.45 - Automated Fire Detection from Wildfire Alert Cameras

Existing California wildfire camera infrastructure is a passive and human operated system where cameras are manually operated and used to confirm satellite heat detections or IRWIN alerts.[65] It is important to identify the location of an ignition in the initial stage of a wildfire to suppress it while the scale is manageable. The goal of EPIC 3.45 is demonstrate that machine learning and enhanced camera/computer vision technologies can provide an alternative to existing wildfire ignition detection methods with a reduced ignition to detection time with low false positive and false negative rates. These novel techniques will be integrated into the Hazard Awareness and Warning Center (HAWC) capabilities and workflow and has a viewshed goal of 90 percent of High Fire Threat District (HFTD) Tier 2 and Tier 3. The project will also evaluate enhanced features such as nighttime detection and triangulation accuracy.

Benefits

- **Safety**
  - This project would enable faster detection of fires and this would allow for faster notification of first responders to move resources to the right place to suppress the fire. As a result, this would help reduce the frequency and/or severity of catastrophic fires.
- **Economic Benefits**
  - PG&E will have access to 600 cameras by end of 2022 from 486 in 2021. Rather than manually monitoring these cameras, this project could result in no additional staff for extra manual camera observations. The faster ignition to detection time enabled by this project would reduce the severity of wildfires and reduce the damage to property.
- **Environmental Benefits**
  - This project would result in a reduction in fire severity which would reduce GHG emissions and particulate matter from wildfire smoke.

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65. https://www.alertwildfire.org/.

- **Support of CPUC Proceedings or State Requirements**
    - R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans

Project 3.46 - Advanced Electric Inspection Tools for Wood Poles

This project seeks to develop a new, non-destructive testing method to analyze the condition of wood poles to provide a more complete analysis of the overall health and condition of existing wood poles. The proposed non-destructive method is radiographic testing (RT) which is where radiation is passed through an object and the material density and thickness absorbs the radiation and reveals the internal composition without the need for intrusive testing.

Benefits

- **Reliability**
    - PG&E identifies approximately 10,000 wood poles for replacement and 4,000 wood poles for reinforcement every year. This project would provide quality data that depicts wood pole health and condition. This better data may either help identify more wood poles that should be replaced or repaired, or it may support a reduction in wood pole replacements due the higher quality data on pole health and condition.
- **Economic Benefits**
    - This better data may either help identify wood poles that should be replaced or repaired, or it may support a reduction in wood pole replacements due the higher quality data on pole health and condition.

Project 3.47 - Operational Vegetation Management Efficiency Through Novel Onsite Equipment

This project's objectives are to complete one or more technology demonstrations which could improve upon such wood handling metrics when deployed at scale. Two technologies that will be solicited in the RFP are wood baling and mobile torrefaction. Baling is expected to reduce labor requirements and processing costs. Mobile torrefaction is a process to create valuable products from heat treating woody biomass and could eliminate 'tipping fees' while having an added benefit of reducing the carbon intensity of our energy portfolio.

Benefits

- **Safety**
  - Vegetation management is a huge undertaking at PG&E and has many hazards. This project would result in fewer truck loads and vehicle trips and would reduce the number of hours workers spend in vehicles.
  - There is increased safety due to less frequent use of dangerous chippers.
- **Economic Benefits**
  - The forecasted cost of enhanced vegetation and wood management is about $40M per year. Wood disposal costs vary year to year but could be expected to be roughly $100M per year. The fraction of PG&E wood management costs displaced will depend on the success of the technology demonstrations of this project. Assuming even a small improvement in efficiency would result in millions of dollars of savings per year.
- **Environmental Benefits**
  - The project would result in lower GHG emissions and air pollution through a reduction of vehicle travel with fewer vegetation management crews.
  - Some proposed technologies also propose carboned sequestration which would reduce GHG emissions.
- **Support of CPUC Proceedings or State Requirements**

- R.18-10-007 Order Instituting Rulemaking to Implement Electric Utility Wildfire Mitigation Plans

APPENDIX D: Alignment of PG&E's EPIC 4 Investment Plan with DER Action Plan Version 2.0

PG&E's EPIC 4 Investment Plan filed on October 3, 2022 includes a number of topics that are aligned with, and supportive of, the goals and actions detailed in the Commission's DER Action Plan Version 2.0. Research Topics within PG&E's EPIC 4 Investment Plan would apply to the following Tracks, Vision Elements, and Action Elements of the DER Action Plan Version 2.0:

DER Action Plan Track	**Vision Element**	**Supported by PG&E EPIC 4 Investment Plan**
Track 1 Load Flexibility and Rates	1A	11. Interconnection Enablement, 12. Advanced Distribution Power Flow Management
	1D	12. Advanced Distribution Power Flow Management
	1E - 1F	12. Advanced Distribution Power Flow Management
	1G	12. Advanced Distribution Power Flow Management
	1H	12. Advanced Distribution Power Flow Management, 13. Electric Vehicle Charging and Integration Enablement
Track 2 Load Flexibility and Rates	2A	12. Advanced Distribution Power Flow Management
	2C	1. Microgrid Enablement, 3. Long Duration Energy Storage, 4. Integration of New Generation Technologies, 11. Interconnection Enablement, 12. Advanced Distribution Power Flow Management, 13. Electric Vehicle Charging and Integration Enablement
	2D	1. Microgrid Enablement, 12. Advanced Distribution Power Flow Management, 13. Electric Vehicle Charging and Integration Enablement
	2E	6. Grid Scenario Planning, 11. Interconnection Enablement, 12. Advanced Distribution Power Flow Management
Track 3 Market Integration	3A-3C	3. Long Duration Energy Storage, 12. Advanced Distribution Power Flow Management, 13. Electric Vehicle Charging and Integration Enablement
Track 4 DER Customer Programs	4F	14. Electric Vehicle Battery Re-Use for Stationary Energy Storage

Track 1: Load Flexibility and Rates

Vision Element 1A: Available dynamic and real time pricing rate options that address load flexibility

This vision element is supported by PG&E's EPIC 4 Investment Plan Topic 11, "Interconnection Enablement", and Topic 12, "Advanced Distribution Power Flow Management", as these topics will yield projects that develop and demonstrate technologies that ~~include~~enable load flexibility and compensation models. Such demonstrations and increased visibility into distribution systems could inform the vision element goal of understanding customer preference for dynamic rates and generation rate components.

Vision Element 1D: Available rates reflect cost causation and provide opportunities for fair compensation

Topic 12, "Advanced Distribution Power Flow Management", supports this vision element's Action Element 3 through the demonstration of compensation mechanisms for DER owners that participate in grid support activities that would inform a proposal for opt-in and opt-out rates for this customer segment. Demonstrations of local DER orchestration will be needed to evaluate available technologies, determine regulatory pathways, and determine fair compensation options.

Vision Elements 1E-1F: Time-varying rate options are available to load management technologies through pricing platform and communicated to all customer segments

Topic 12, "Advanced Distribution Power Flow Management", indirectly supports this Vision Element through informing of some of the costs that would feed into rate design as well as the pricing platform, and subscription services.

Vision Element 1H: Electric Vehicle-related assets owners and managers respond to price or load management signals that reflect real-time and dynamic costs and benefits of charging

Topic 12, "Advanced Distribution Power Flow Management", and Topic 13, "Electric Vehicle Charging and Integration Enablement", support this Vision Element through the demonstration of flexible load management and compensation mechanisms for BTM energy storage and EV owners that participate in ~~grid support activities,~~ optimized managed EV charging load, as well as energy export services (vehicle-to-grid exports).

Track 2: Grid Infrastructure

Vision Element 2A: CPUC to guide utilities to modernize the electric grid for a high DER future

Topic 12, "Advanced Distribution Power Flow Management", supports Vision Element 2A with the development and demonstration of an automated operational tool that would coordinate and optimize dispatching of all available FTM DERs as well as BTM DERs including EVs and flexible loads. Additionally, the tool would provide hourly and day ahead distribution forecasts for a feeder. This topic would also inform PG&E on how such a tool would progress toward operationalization in a Distribution System Operator (DSO) model. Such a tool would enable localized DER orchestration and support the vision for a high DER grid in line with State policy objectives.

Vision Element 2C: Continuously improve interconnection performance, leading to greater transparency, cybersecurity, speed, and cost certainty

This vision element's Action Element 1 is supported by Topic 11, "Interconnection Enablement", through reducing or eliminating the time it takes to complete the interconnection for DERs thereby supporting DER adoption in line with California's clean energy goals. The aim of Topic 11 is to speed or eliminate interconnection queue time through exploring and preparing to operationalize a wide range of solutions for eliminating barriers to timely, smarter, more flexible customer service connection and generation interconnection. This would be done through making more efficient use of limited available distribution service capacity and avoiding significant grid infrastructure upgrades that would bring long lead times and investment challenges.

This vision element's Action Element 2 is supported by Topic 1, "Microgrid Enablement", as an aim of this topic is to develop standardized microgrid designs and validated equipment and configuration lists that can help reduce the cost of DER integration or optimize the benefits of the DERs within microgrids. This Action Element 2 is also supported by Topic 2, “Individual Customer Resiliency”, with its backup power transfer meters and other related grid equipment, that would inform the envisioned transparent technical review process.

This vision element’s Action Element 3 is supported by Topic 12, “Advanced Distribution Power Flow Management”, and its expansion of the use of the IEEE 2030.5 communications protocol for telemetry and its use of advanced smart inverter control functions for operational flexibility.

This vision element’s Action Element 4 is supported by Topic 13, “Electric Vehicle Charging and Integration Enablement”, with its intent to establish methods to automatically detect and track the installation of V2G interconnections, then informing the ADMS/DERMS in coordinating BTM DERs.

This vision element’s Action Element 6 is supported by Topic 3, “Long Duration Energy Storage”, Topic 1, “Microgrid Enablement”, and Topic 4, “Integration of New Generation Technologies”, as each of these topics include hydrogen-based fuel creation, generation, and storage demonstrations. The projects within these three topics would establish methods for tracking energy stored in the form of hydrogen and subsequently returned to the grid, including tracking the method of production for that stored hydrogen.

Vision Element 2D: Implement new standards to facilitate visibility, operational control, provision of grid services, and interoperability of DERs, while maintaining cybersecurity

This vision element’s Action Elements 1-4 are supported by Topic 1, “Microgrid Enablement”, Topic 12, “Advanced Distribution Power Flow Management”, and Topic 13, “Electric Vehicle Charging and Integration Enablement”, as these three topics will yield projects that advance smart inverter operationalization use case demonstration, interoperability of DERs, as well as identify, enhance or establish standards and best practices needed to facilitate the interoperability of DERs on the evolving distribution grid.

Vision Element 2E: Integrate impacts of electrification into distribution planning to maximize public benefits, minimize costs, and optimize deployment of complimentary and supporting infrastructure

This vision element's Action Element 1 is supported by Topic 6, "Grid Scenario Planning," Topic 11, "Interconnection Enablement", and Topic 12, "Advanced Distribution Power Flow Management", as projects within these topics would aim to demonstrate the optimization of distribution grid investments in a high DER scenario, including through automated load management and flexible interconnection, and thus could inform the envisioned study.

Track 3: Market Integration

Vision Elements 3A-3C: Enable Energy storage and hybrid configurations with other DERs to participate in wholesale markets, determine fair compensation, rules, and procedures for DER participation

These vision elements are supported by a combination of Topic 3, "Long Duration Energy Storage", and Topic 12, "Advanced Distribution Power Flow Management", along with Topic 13, "Electric Vehicle Charging and Integration Enablement", as these topics can inform methods to efficiently integrate all types of energy storage technologies and to create compensation mechanisms that support the State's goals. In addition, projects within Topic 23, "Granular Attributes for Environmental Commodity Tracking", would support the additional participation of DERs in markets through the demonstration of an additional price signal for renewable generation.

Track 4. DER Customer Programs

Vision Element 4C-D: Understanding the impact of DER programs on middle-income ratepayers and ESJ and tribal communities is an inherent part of program design and management

These vision elements are supported by PG&E's commitment to equity as an underlining principle of EPIC planning, project design, demonstration, and stakeholder engagement throughout the project, as described in "Chater 1: Introduction and Background" of the EPIC 4 Investment Plan.

Vision Element 4F: End-of-life management programs are in place to ensure the effective collection, safe transport, and environmentally responsible recycling or re-use of DERs

Action Element 2 is supported by Topic 14, "Electric Vehicle Battery Re-Use for Stationary Energy Storage", as this topic targets second life for electric vehicle batteries in energy storage systems and could therefore inform recommendations and programs that ensure the effective and environmentally responsible re-use or recycling of batteries at their end of life.

APPENDIX E: Alignment of PG&E's EPIC 4 Investment Plan with CPUC Environmental and Social Justice Action Plan

PG&E continues to support including equity as a guiding EPIC principle. In this EPIC 4 Investment Plan, we have proposed a set of 23 Research Topics that ~~it expects~~is expected to provide a wide range of equity benefits, including health and safety benefits and financial benefits. These Research Topics align with and advance the CPUC's Environmental and Social Justice Action Plan Goals. Listed below in the table are the CPUC ESJ Action Plan Goals applicable to PG&E.

Applicable CPUC ESJ Action Plan Goal	Supported by PG&E EPIC 4 Investment Plan
1. Consistently integrate equity and access considerations throughout CPUC regulatory activities	See written section below.
2. Increase investment in clean energy resources to benefit ESJ communities	Topic 1. Microgrid Enablement
	Topic 2. Individual Customer Resilience ~~Research Topic~~
	Topic 13. Electric Vehicle Charging and Integration Enablement
3. Strive to improve access to high-quality water, communications, and transportation services for ESJ communities.	Topic 13. Electric Vehicle Charging and Integration Enablement
4. Increase climate resiliency in ESJ communities	Topic 1. Microgrid Enablement
	Topic 2. Individual Customer Resilience
	Topic 3. Long Duration Energy Storage
	Topic 13. Electric Vehicle Charging and Integration Enablement
	Topic 16. Undergrounding Capabilities
5. Enhance outreach and public participation opportunities for ESJ communities to meaningfully participate in the CPUC's decision-making process and benefit from CPUC programs	See written section below.
7. Promote high road career paths and economic opportunity for residents of ESJ communities	Topic 21. Climate and Nature-Positive Operations
9. Monitor the CPUC's ESJ efforts to evaluate how they are achieving their objectives	See written section below.

Goal 1. Consistently integrate equity and access considerations throughout CPUC regulatory activities

PG&E integrates equity and access considerations into both the development process (procedural equity) and implementation (distributional equity) of the EPIC 4 Investment Plan.

As part of the development of the EPIC 4 Investment Plan, PG&E hosted two workshops for the general public, two workshops for DAC representative groups, as well as numerous consultation meetings with the CPUC and CEC. These workshops, as a whole, were well-attended with a broad spectrum of participants, including academia, industry, and research institutions, as well as environmental, customer advocates and community-based organizations. Additionally, PG&E has collaborated with the PG&E Community Perspectives Advisory Committee (CPAC) to incorporate broader community feedback and identify opportunities to partner with communities to host projects that will have field demonstration components. ~~Feedback was incorporated into the 23 Research Topics and their alignment with the DACAG Equity Framework.~~

Implementing the EPIC 4 Investment Plan will include dedicating at least 25 percent of technology demonstration and deployment (TD&D) funds toward projects located in and benefitting disadvantaged communities and at least an additional 10 percent allocation of TD&D funds toward projects located in and benefitting low-income communities.

Goal 2. Increase investment in clean energy resources to benefit ESJ communities, especially to improve local air quality and public health

Topic 1, "Microgrid Enablement" will explore solutions to provide clean, back-up power for remote areas, providing emissions-free service, and in some instances also reducing wildfire risk. Disadvantaged and low-income communities, especially in the wildland urban interface and high fire threat districts, will be engaged to help with demonstrations and resulting benefits from it in those communities.

Topic 2, “Individual Customer Resilience,” will demonstrate technologies to provide customer greater resiliency at lower costs for individual residential and non-residential customers impacted by Public Safety Power Shutoffs (PSPS) and Enhanced Powerline Safety Settings (EPSS) events. DERs support individual customer resilience through clean, non-polluting energy, like electric vehicles and energy battery storage. This strategy can avoid the need for diesel generators, fires, and other polluting sources of energy or heat, contributing to improved local air quality and public health.

Topic 13, “Electric Vehicle Charging and Integration Enablement Research Topic,” seeks to accelerate both the adoption and expanded access of electric vehicles, especially in ESJ communities. Disadvantaged and low-income communities will be targeted for demonstration to help with transportation electrification and attendant benefits from it in those communities. Since DACs might not have the high penetration of EVs that would be needed as the basis to conduct the demonstrations, PG&E will look for opportunities to align EPIC funds with resources from other customer programs and upcoming Federal funding opportunities to provide communities with the EVs needed as the basis for the demonstrations. When conducting ~~pilot~~demonstration projects, transportation electrification can reduce internal combustion engine emissions, and improve~~s~~ air quality in the ~~DACs~~communities where technology is demonstrated.

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Goal 3. Strive to improve access to high-quality water, communications, and transportation services for ESJ communities.

Topic 13, “Electric Vehicle Charging and Integration Enablement,” seeks to accelerate both the adoption and expanded access of electric vehicles, especially in ESJ communities. Disadvantaged and low-income communities will be targeted for demonstration to help with transportation electrification and attendant benefits from it in those communities.

Goal 4. Increase climate resiliency in ESJ communities

Given the increasing frequency of heat waves, intensity of drought, and intensity of storms from climate change, climate resilience continues to be a major focus of the EPIC Program.

Topic 1, "Microgrid Enablement" will explore solutions making electricity service for remote areas significantly more reliable, reducing or eliminating disruptions caused by extreme weather-related power outage events, ~~helping mitigate capacity constraints,~~ providing emissions-free service, and in some instances also reducing wildfire risk. Disadvantaged and low-income communities, especially in the wildland urban interface and high fire threat districts, will be targeted for demonstration to help with ~~pilots~~demonstrations and resulting benefits from it in those communities.

Topic 2, "Individual Customer Resilience" will demonstrate technologies to provide customer greater resiliency at lower costs for individual residential and non-residential customers impacted by power shutoff events.

As unpredictable and extreme weather conditions continue to impact California as a result of climate change, Topic 3, "Long Duration Energy Storage," can play a critical role in ensuring electric reliability across long periods of low renewable generation and even across seasons. By demonstrating technologies in disadvantaged and low-income communities, these customers can see the local benefits of increased electric reliability.

Topic 13, "Electric Vehicle Charging and Integration Enablement" will explore how customers could use vehicle-to-anything (V2X) integration for customer resiliency for planned and unplanned grid outages, in support of the electric grid, or for other potentially beneficial use cases. Disadvantaged communities and low-income will be targeted for demonstration to help with V2X enablement and resulting benefits from it in those communities.

Topic 16, "Undergrounding Capabilities," will demonstrate emerging technologies that have the potential to increase the speed, efficiency, and predictability of undergrounding, as well as potentially extend the life of assets with intelligent monitoring. Improvements in these areas would lead to ~~lower costs for customers, quicker~~faster reduction of wildfire risk in these areas ~~,~~

and maintaining longer asset life, without jeopardizing safety and reliability. Vulnerable communities in high fire risk areas could have service undergrounded sooner than otherwise would be possible, reducing their exposure to wildfire risk and reducing wildfire-related public health impacts.

Goal 5. Enhance outreach and public participation opportunities for ESJ communities to meaningfully participate in the CPUC's decision-making process and benefit from CPUC programs

By requiring that all EPIC Administrators dedicate at least 25 percent of technology demonstration and deployment (TD&D) funds toward projects located in and benefiting disadvantaged communities and at least an additional 10 percent allocation of TD&D funds toward projects located in and benefitting low-income communities, the EPIC Program directly benefits ESJ Communities and engenders opportunity for public participation.

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Goal 7. Promote high road career paths and economic opportunity for residents of ESJ communities

Topic 21, "Climate and Nature-Positive Operations," will assess technology options and conduct demonstrations of climate and nature-positive solutions. For instance, PG&E seeks to improve operational efficiency, environmental performance, and worker safety across the woody biomass value chain from locational targeting to collection, in situ processing, removal, and development of value-added carbon re-use products. Under-resourced rural and ESJ communities could benefit both from improved public safety and potential new economic opportunity associated with climate and environment-positive value chains.

Goal 9. Monitor the CPUC's ESJ efforts to evaluate how they are achieving their objectives

In each Research Topic section, PG&E identifies potential metrics and performance indicators to track in future projects. In addition to tracking the budget related to TD&D work, PG&E will seek to capture qualitative and quantitative benefits of demonstrations in disadvantaged and low-income communities. Metrics will be shared in the EPIC Annual Report, as well as, in each project's final report.

APPENDIX F: Alignment of PG&E's EPIC 4 Investment Plan with Department of Energy Justice40 Initiative

In 2021, the Biden Administration institutionalized the federal government's commitment to environmental justice through the Executive Order 14008 and it's Justice40 Initiative. Justice40 aims to ensure "that 40 percent of the overall benefits of certain Federal investments flow to disadvantaged communities that are marginalized, underserved, and overburdened by pollution."[66] Investment categories include: climate change, clean energy and energy efficiency, clean transit, affordable and sustainable housing, training and workforce development, remediation and reduction of legacy pollution, and the development of critical clean water and wastewater infrastructure.[67] Listed below in the table are the Justice40 Investment Categories applicable to PG&E.

Applicable Justice40 Investment Category	Supported by PG&E EPIC 4 Investment Plan
Climate Change	Topic 1. Microgrid Enablement
	Topic 2. Individual Customer Resilience
	Topic 3. Long Duration Energy Storage
	Topic 13. Electric Vehicle Charging and Integration Enablement
	Topic 16. Undergrounding Capabilities
Clean Energy and Energy Efficiency	Topic 1. Microgrid Enablement
	Topic 2. Individual Customer Resilience Research Topic
	Topic 11. Interconnection Enablement
	Topic 13. Electric Vehicle Charging and Integration Enablement
Clean Transit	Topic 13. Electric Vehicle Charging and Integration Enablement
	Topic 14. Electric Vehicle Battery Re-Use for Stationary Energy
Training and Workforce Development	Topic 21. Climate and Nature-Positive Operations

[66] https://www.whitehouse.gov/environmentaljustice/justice40/

[67] Interim Implementation Guidance for the Justice40 Initiative, https://www.whitehouse.gov/wp-content/uploads/2021/07/M-21-28.pdf, (2021)

Climate Change

Given the increasing frequency of heat waves, intensity of drought, and intensity of storms from climate change, climate resilience continues to be a major focus of the EPIC Program.

Topic 1, "Microgrid Enablement" will explore solutions making electricity service for remote areas significantly more reliable, reducing or eliminating disruptions caused by extreme weather-related power outage events, ~~helping mitigate capacity constraints,~~ providing emissions-free service, and in some instances also reducing wildfire risk. Disadvantaged and low-income communities, especially in the wildland urban interface and high fire threat districts, will be targeted for demonstration to help with ~~pilots~~demonstrations and resulting benefits from it in those communities.

Topic 2, "Individual Customer Resilience" will demonstrate technologies to provide customer greater resiliency at lower costs for individual residential and non-residential customers impacted by power shutoff events.

As unpredictable and extreme weather conditions continue to impact California as a result of climate change, Topic 3, "Long Duration Energy Storage," can play a critical role in ensuring electric reliability across long periods of low renewable generation and even across seasons. By demonstrating technologies in disadvantaged and low-income communities, these customers can benefit from increased local electric reliability.

Topic 13, "Electric Vehicle Charging and Integration Enablement" will explore how customers could use vehicle-to-anything (V2X) integration for customer resiliency for planned and unplanned grid outages, in support of the electric grid, or for other potentially beneficial use cases. Disadvantaged and low-income communities will be targeted for demonstration to help with V2X ~~pilots~~demonstrations and resulting benefits from it in those communities.

Topic 16, "Undergrounding Capabilities," will demonstrate emerging technologies that have the potential to increase the speed, efficiency, and predictability of undergrounding, as well as potentially extend the life of assets with intelligent monitoring. Improvements in these areas would lead to lower costs for customers, quicker reduction of wildfire risk in these areas, and maintaining longer asset life, without jeopardizing safety and reliability. Vulnerable communities in high fire risk areas could have service undergrounded sooner than otherwise would be possible, reducing their exposure to wildfire risk and reducing wildfire-related public health impacts.

Clean Energy and Energy Efficiency

Topic 1, "Microgrid Enablement" will explore solutions to provide clean, back-up power for remote areas, providing emissions-free service, and in some instances also reducing wildfire risk. Disadvantaged and low-income communities, especially in the wildland urban interface and high fire threat districts, will be engaged to help with demonstrations and resulting benefits from it in those communities.

Topic 2, "Individual Customer Resilience," will demonstrate technologies to provide customer greater resiliency at lower costs for individual residential and non-residential customers impacted by Public Safety Power Shutoffs (PSPS) and Enhanced Powerline Safety Settings (EPSS) events. DERs support individual customer resilience by providing clean, non-polluting electricity, through electric vehicles and energy battery storage. This strategy can avoid the need for diesel generators, fires, and other polluting sources of energy or heat, contributing to improved local air quality and public health.

Topic 11, "Interconnection Enablement," will demonstrate a range of solutions for enabling the interconnection of distributed energy resources and new service connections of new and growing residential and commercial customers' loads and DERs, beyond conventional upgrades to conductors and transformers or the establishment of static constraints as a prerequisite for interconnection. Accelerating interconnection enablement is a critical step in removing barriers for disadvantaged and low-income customers to access clean DERs within their communities.

Topic 13, "Electric Vehicle Charging and Integration Enablement Research Topic," seeks to accelerate both the adoption and expanded access of electric vehicles, especially in ESJ communities. Disadvantaged and low-income communities will be targeted for demonstration to help with transportation electrification and attendant benefits from it in those communities. When conducting demonstrations, transportation electrification can reduce internal combustion engine emissions, improves air quality in the DACs where technology is demonstrated.

~~The~~

Clean Transit

Topic 13, “Electric Vehicle Charging and Integration Enablement,” seeks to accelerate both the adoption and expanded access of electric vehicles, especially in ESJ communities. Disadvantaged and low-income communities will be targeted for demonstration to help with transportation electrification and attendant benefits from it in those communities.

Topic 14, “Electric Vehicle Battery Re-Use for Stationary Energy,” intends to conduct demonstration and analysis to identify key utility requirements for the efficient and effective deployment of second-life batteries as grid scale resources. In addition to extending the life span of electric vehicle batteries, PG&E customers could also benefit from lower energy bills as grid-connected energy storage built with second-life batteries may be less expensive than that built with new batteries.

Training and Workforce Development

Topic 21, “Climate and Nature-Positive Operations,” will assess technology options and conduct demonstrations of climate and nature-positive solutions. For instance, PG&E seeks to improve operational efficiency, environmental performance, and worker safety across the woody biomass value chain from locational targeting to collection, in situ processing, removal, and development of value-added carbon re-use products. Under-resourced rural and ESJ communities could benefit both from improved public safety and potential new economic opportunity associated with climate and environment-positive value chains.

PG&E Gas and Electric
Advice Submittal List
General Order 96-B, Section IV

AT&T
Albion Power Company

Alta Power Group, LLC
Anderson & Poole

Atlas ReFuel
BART
Buchalter
Barkovich & Yap, Inc.
Braun Blaising Smith Wynne, P.C.
California Community Choice Association
California Cotton Ginners & Growers
Assn California Energy Commission

California Hub for Energy Efficiency Financing

California Alternative Energy and Advanced Transportation Financing Authority
California Public Utilities Commission
Calpine

Cameron-Daniel, P.C.
Casner, Steve
Center for Biological Diversity

Chevron Pipeline and Power
City of Palo Alto

City of San Jose
Clean Power Research
Coast Economic Consulting
Commercial Energy
Crossborder Energy
Crown Road Energy, LLC
Davis Wright Tremaine LLP
Day Carter Murphy

Dept of General Services
Don Pickett & Associates, Inc.
Douglass & Liddell
Downey Brand LLP
Dish Wireless L.L.C.

East Bay Community Energy Ellison
Schneider & Harris LLP

Electrical Power Systems, Inc.
Fresno
Engineers and Scientists of California

GenOn Energy, Inc.
Green Power Institute
Hanna & Morton
ICF
iCommLaw
International Power Technology
Intertie

Intestate Gas Services, Inc.

Johnston, Kevin
Kelly Group
Ken Bohn Consulting
Keyes & Fox LLP
Leviton Manufacturing Co., Inc.

Los Angeles County Integrated Waste Management Task Force
MRW & Associates
Manatt Phelps Phillips
Marin Energy Authority
McClintock IP
McKenzie & Associates

Modesto Irrigation District
NRG Solar

OnGrid Solar
Pacific Gas and Electric Company
Peninsula Clean Energy

Pioneer Community Energy

Public Advocates Office

Redwood Coast Energy Authority
Regulatory & Cogeneration Service, Inc.

Resource Innovations

SCD Energy Solutions
San Diego Gas & Electric Company

SPURR
San Francisco Water Power and Sewer
Sempra Utilities

Sierra Telephone Company, Inc.
Southern California Edison Company
Southern California Gas Company
Spark Energy
Sun Light & Power
Sunshine Design
Stoel Rives LLP

Tecogen, Inc.
TerraVerde Renewable Partners
Tiger Natural Gas, Inc.

TransCanada
Utility Cost Management
Utility Power Solutions
Water and Energy Consulting Wellhead
Electric Company
Western Manufactured Housing Communities Association (WMA)
Yep Energy