SOUTHERN CALIFORNIA EDISON®
An *EDISON INTERNATIONAL*® Company

Connor J Flanigan
Managing Director, State Regulatory Operations

April 30, 2025

ADVICE 5538-E
(U 338-E)

PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA
COMMUNICATIONS DIVISION

SUBJECT: Submission of Electric Program Investment Charge (EPIC)
Annual Report

PURPOSE AND BACKGROUND

In Ordering Paragraph 16 of Decision No. 12-05-037, the California Public Utilities Commission (Commission) ordered Southern California Edison Company (SCE) and the other Electric Program Investment Charge (EPIC) administrators to file an annual report concerning the status of their respective EPIC programs. More recently, in Ordering Paragraph 8 of Decision No. 23-04-042, the Commission ordered that the annual report should be submitted via a Tier 2 advice letter. Pursuant to the Commission's direction in Decision No. 23-04-042, attached to this advice letter is SCE's 2023 annual report.

No cost information is required for this advice filing.

This advice filing will not increase any rate or charge, cause the withdrawal, of service, or conflict with any other schedule or rule.

TIER DESIGNATION

Pursuant to OP 8 of Decision No. 23-04-042, this advice letter is submitted with a Tier 2 designation.

EFFECTIVE DATE

This advice filing will become effective on May 30, 2025, the 30th calendar day after the date submitted.

<u>NOTICE</u>

Anyone wishing to protest this advice letter may do so only electronically. Protests must be received no later than 20 days after the date of this advice letter. Protests should be submitted to the CPUC Energy Division at:

E-mail: EDTariffUnit@cpuc.ca.gov

In addition, protests and all other correspondence regarding this advice letter should also be sent electronically to the attention of:

Connor Flanigan
Managing Director, State Regulatory Operations
Southern California Edison Company
E-mail: AdviceTariffManager@sce.com

Adam Smith
Director, Regulatory Relations
Southern California Edison Company
c/o Karyn Gansecki
E-mail: Karyn.Gansecki@sce.com

Gloria Ing
Senior Attorney
Southern California Edison Company
E-mail: Gloria.Ing@sce.com

and

Richard Kwee
Program Manager
Southern California Edison Company
E-mail: Richard.1.Kwee@sce.com

There are no restrictions on who may submit a protest, but the protest shall set forth specifically the grounds upon which it is based and must be received by the deadline shown above.

In accordance with General Rule 4 of GO 96-B, SCE is serving copies of this advice letter to the interested parties shown on the attached GO 96-B and R.13-11-005 service list. Address change requests to the GO 96-B service list should be directed by electronic mail to AdviceTariffManager@sce.com or at (626) 302-4747. For changes to all other service lists, please contact the Commission's Process Office at (415) 703- 2021 or by electronic mail at Process_Office@cpuc.ca.gov. Pursuant to Ordering Paragraph 16 of Decision No. 12-05-037, SCE is also serving a copy of this advice letter on (1) parties on the A. 22-10-001 and R. 19-10-005 service lists, which are the most recent EPIC proceedings, (2) parties on the service list of A. 23-05-010, A. 22-05- 016, and A. 21-06-021, which are the most recent general rate case proceedings of the electric investor owned utilities and EPIC administrators, and (3) the applicants seeking EPIC awards in 2024. Pursuant to the Energy Division's directions in its April 24, 2024 email, SCE is also submitting this Advice Letter directly to the Energy Division.

To view other SCE advice letters submitted with the Commission, log on to SCE's web site at https://www.sce.com/wps/portal/home/regulatory/advice-letters.

For questions, please contact Gloria Ing at (626) 302-1999 or by electronic mail at Gloria.Ing@sce.com.

Southern California Edison Company

/s/ Connor J Flanigan
Connor J Flanigan

Enclosures

cc: Leuwam.Tesfai@cpuc.ca.gov
        Fredric.Beck@cpuc.ca.gov

California Public Utilities Commission

ADVICE LETTER SUMMARY
ENERGY UTILITY

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

Company name/CPUC Utility No.:

Utility type:	Contact Person:
☐ ELC ☐ GAS ☐ WATER	Phone #:
☐ PLC ☐ HEAT	E-mail:
	E-mail Disposition Notice to:

EXPLANATION OF UTILITY TYPE	(Date Submitted / Received Stamp by CPUC)
ELC = Electric GAS = Gas	
PLC = Pipeline HEAT = Heat WATER = Water	

Advice Letter (AL) #:   Tier Designation:

Subject of AL:

Keywords (choose from CPUC listing):

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

If AL submitted in compliance with a Commission order, indicate relevant Decision/Resolution #:

Does AL replace a withdrawn or rejected AL? If so, identify the prior AL:

Summarize differences between the AL and the prior withdrawn or rejected AL:

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: No. of tariff sheets:

Estimated system annual revenue effect (%):

Estimated system average rate effect (%):

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:

Service affected and changes proposed[1]:

Pending advice letters that revise the same tariff sheets:

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

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:
Title:
Utility/Entity Name:

Telephone (xxx) xxx-xxxx:
Facsimile (xxx) xxx-xxxx:
Email:

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

ENERGY Advice Letter Keywords

Affiliate	Direct Access	Preliminary Statement
Agreements	Disconnect Service	Procurement
Agriculture	ECAC / Energy Cost Adjustment	Qualifying Facility
Avoided Cost	EOR / Enhanced Oil Recovery	Rebates
Balancing Account	Energy Charge	Refunds
Baseline	Energy Efficiency	Reliability
Bilingual	Establish Service	Re-MAT/Bio-MAT
Billings	Expand Service Area	Revenue Allocation
Bioenergy	Forms	Rule 21
Brokerage Fees	Franchise Fee / User Tax	Rules
CARE	G.O. 131-D	Section 851
CPUC Reimbursement Fee	GRC / General Rate Case	Self Generation
Capacity	Hazardous Waste	Service Area Map
Cogeneration	Increase Rates	Service Outage
Compliance	Interruptible Service	Solar
Conditions of Service	Interutility Transportation	Standby Service
Connection	LIEE / Low-Income Energy Efficiency	Storage
Conservation	LIRA / Low-Income Ratepayer Assistance	Street Lights
Consolidate Tariffs	Late Payment Charge	Surcharges
Contracts	Line Extensions	Tariffs
Core	Memorandum Account	Taxes
Credit	Metered Energy Efficiency	Text Changes
Curtailable Service	Metering	Transformer
Customer Charge	Mobile Home Parks	Transition Cost
Customer Owned Generation	Name Change	Transmission Lines
Decrease Rates	Non-Core	Transportation Electrification
Demand Charge	Non-firm Service Contracts	Transportation Rates
Demand Side Fund	Nuclear	Undergrounding
Demand Side Management	Oil Pipelines	Voltage Discount
Demand Side Response	PBR / Performance Based Ratemaking	Wind Power
Deposits	Portfolio	Withdrawal of Service
Depreciation	Power Lines	

EPIC ADMINISTRATOR ANNUAL REPORT FOR 2024 ACTIVITIES

EPIC ADMINISTRATOR ANNUAL REPORT FOR 2024 ACTIVITIES

TABLE OF CONTENTS

1. Executive Summary

a) Overview of Programs/Plan Highlights

2024 represented the eleventh full year of implementing EPIC program operations since receiving the California Public Utilities Commission (Commission) approval of SCE's EPIC 1 application[1] on November 19, 2013.[2] This program is funded by California utility customers under the auspices of the California Public Utilities Commission. Furthermore, 2024 represented nearly the ninth full year of implementing program operations of SCE's 2015 – 2017 Investment Plan Application[3] (EPIC 2) after receiving Commission approval on April 9, 2015.[4] 2024 represented SCE's sixth full year of implementing program operations of SCE's 2018 – 2020 Investment Plan Application[5] (EPIC 3) after receiving approval on October 25, 2018.[6] Lastly, 2024 represented SCE's first year of implementing program operations of SCE's 2021 – 2025 Investment Plan[7] (EPIC 4) after receiving approval on November 30, 2023,[8] and SCE launched five new projects.

The SCE project teams made notable advancements throughout 2024 across SCE's EPIC project portfolio. Notable advancements include:

- Completing the Advanced Comprehensive Hazards Tool project which successfully demonstrated two innovative grid resiliency tools, both utilizing a centralized data architecture, to perform vulnerability assessments and inform hazard mitigation efforts for 1) substation earthquake risk, and 2) low-voltage distribution infrastructure risk from high winds, which could ultimately improve reliability and safety.

- Completing the Control and Protection for Microgrids and Virtual Power Plants project, which provided SCE with the opportunity to create a test bed to thoroughly

---

[1] A.12-11-001.
[2] D.13-11-025, OP8.
[3] A.14-05-005.
[4] D.15-04-020, OP1.
[5] A.17-05-005.
[6] D.18-10-052, OP2.
[7] A.22-10-001.
[8] D.23-11-086, OP1.

examine Microgrid Control Systems (MCS) and identify potential operational challenges, helping to ensure a seamless integration process in the field, while minimizing disruptions and maximizing the benefits of microgrids. Microgrids provide a foundation to increase the value of Distributed Energy Resources (DERs). The successful completion of the project increases the opportunities to further deploy microgrids and DERs, with immediate usefulness to two subsequent EPIC 3 projects: Service and Distribution Centers of the Future and Smart City Demonstration.

- Launching five new EPIC 4 projects that advance EPIC 4 initiatives and aim to benefit Low Income and Disadvantaged Communities (DACs).

As part of SCE's 2025 General Rate Case (GRC), SCE identified several EPIC projects that it aims to transition to capital pilots. SCE is evaluating Smart City and Service and Distribution Centers of the Future, projects from EPIC 3, as candidates to be the first two of these to become capital projects. This transition to capital projects help to move the projects from demonstrations to full solutions that can be implemented broadly.

Key findings and lessons learned across SCE's EPIC projects emphasize the importance of ensuring that the lab testing and resulting models are sufficient to meet SCE's requirements before deploying into a pilot or field operation.

In addition, despite encountering challenges such as delays in procurement and vendors unexpectedly ending production or support for key products in projects, SCE's EPIC project teams have effectively managed these setbacks and continue to drive the projects to completion.

In this report, SCE separately presents the highlights from its EPIC I (2012 – 2014), EPIC II (2015 – 2017), EPIC III (2018 – 2020), and EPIC IV (2021 – 2025) Investment Plans.

(1)   2012 – 2014 Investment Plan

Between January 1 and December 31, 2024, for the 2012 – 2014 Investment Plan, SCE expended a total of $(19,494) toward project costs and $0 toward program administrative

costs. SCE's cumulative expenses over the span of its 2012 – 2014 Investment Plan amount to $ 38,642,227.

SCE executed 16 projects from its approved EPIC 1 portfolio. This includes the completion of three projects in 2015, four projects in 2016, four projects in 2017, two projects in 2018, two projects in 2019 and one project in 2020. A list of completed projects is included in the Conclusion of this Report (section 4.b)(4)). In accordance with the Commission's directives,[9] SCE prepared Final Project Reports for each completed project and included them in the Annual Reports according to the years completed. All EPIC 1 projects are complete as of 2020.

(2)   2015 – 2017 Investment Plan

Between January 1 and December 31, 2024, for the 2015 – 2017 Investment Plan, SCE expended $967,743 toward project costs and $199,458 toward administrative costs for a grand total of $1,167,202. SCE's cumulative expenses for its 2015 – 2017 Investment Plan amount to $39,437,223. SCE committed $843,637 toward projects and encumbered $580,114 through executed purchase orders during this period. SCE had no uncommitted EPIC 2 funding as of December 31, 2023.

SCE initiated 13 projects from its approved EPIC 2 portfolio. As of December 31, 2024, three projects have been cancelled for the reasons described in their respective project updates sections. Project execution activities continued for the remaining 10 projects. Of those 10 projects, SCE completed one project in 2017, three projects in 2018, two projects in 2019, one project in 2020, one project in 2021, and one project in 2022. One project, System Intelligence and Situational Awareness Capabilities, remains in execution in 2024.

(3)   2018 – 2020 Investment Plan

Between January 1 and December 31, 2024, for the 2018 – 2020 Investment Plan, SCE expended a total of $3,013,955 toward project costs and $362,550 toward administrative costs for a grand total of $3,376,505. SCE's cumulative expenses over the span of its 2018 – 2020 Investment Plan amount to $28,511,963. SCE committed $9,431,542 toward projects and encumbered

---

[9]   D.13-11-025, OP14.

$5,557,907 through executed purchase orders during this period. SCE had no uncommitted EPIC 3 project funding as of December 31, 2024.

SCE received approval from the Commission for two replacement projects in 2022: Wildfire Prevention & Resiliency Technologies Demonstration and Beyond Lithium-Ion Energy Storage Demonstration, both of which were included in the Joint Utilities Research Administration Plan (RAP) Application. SCE initiated 19 projects from its approved portfolio. Four of the EPIC 3 projects were either previously cancelled or deferred. Project execution activities continued for the remaining fifteen projects. Of those fifteen projects, SCE completed one in 2021, one in 2022, one in 2023, and two in 2024: Advanced Comprehensive Hazards Tool and Control and Protection for Microgrids and Virtual Power Plants. SCE continues to perform work on the remaining nine projects. The following 10 projects from the EPIC 3 portfolio remain in execution:

1. Advanced Technology for Field Safety (ATFS)

2. Beyond Lithium-ion Energy Storage Demo

3. Distributed Plug-In Electric Vehicle Charging Resources

4. Next Generation Distribution Automation III

5. SA-3 Phase III Field Demonstrations

6. Service and Distribution Centers of the Future

7. Smart City Demonstration

8. Storage-Based Distribution DC Link

9. Vehicle-to-Grid Integration Using On-Board Inverter

10. Wildfire Prevention & Resiliency Technology Demonstration

(4)   2021 – 2025 Investment Plan

Between January 1 and December 31, 2024, for the 2021 – 2025 Investment Plan, SCE expended a total of $4,698 toward project costs and $ $6,098 toward administrative costs for a grand total of $10,796. SCE's cumulative expenses over the span of its 2021 – 2025 Investment Plan amount to $10,796. SCE committed $295,302 toward projects and encumbered $0 through executed

purchase orders during this period. SCE budgeted $39,000,000 to EPIC 4 projects out of its total EPIC 4 project budget of $68,051,325 as of December 31, 2024.

SCE initiated five projects in 2024 based on the Strategic Initiatives and Research Topics approved in the 2021 – 2025 Investment Plan. The following five projects from the EPIC 4 portfolio remain in execution:

1. Flexible Alternating Current System (FACS)

2. ML-Augmented Digital Simulation (MAD-S)

3. Quantum Networking

4. Swift Electrification of Transit (SET)

5. Stability Improvement with DERs (SIDER)

2. Introduction and Overview

a) EPIC Background

In Decision (D.)12-05-037, the Commission established the EPIC Program to fund applied research and development, technology demonstration and deployment (TD&D), and market facilitation programs to provide ratepayer benefits. This program is funded by California utility customers under the auspices of the California Public Utilities Commission. This Decision further stipulates that the EPIC Program will continue through 2020[10] with an annual budget of $162 million,[11] adjusted for inflation.[12] Approximately 80% of the EPIC budget is administered by the California Energy Commission (CEC), and 20% is administered by the investor-owned utilities (IOUs). Additionally, 0.5% of the total EPIC budget funds Commission oversight of the Program.[13] The IOUs are limited to performing TD&D activities.[14] SCE was allocated 41.1% of the IOU portion of the budget and administrative activities.[15]

---

[10] D.12-05-037, OP1.
[11] D.12-05-037, OP7.
[12] Using the Consumer Price Index.
[13] *Id*, OP5.
[14] *Id*.
[15] D.12-05-037, OP 7, as modified by D.12-07-001.

The Commission approved SCE's 2012 – 2014 Investment Plan[16] in D.13-11-025 on November 19, 2013. SCE submitted its 2015 – 2017 Investment Plan Application[17] on May 1, 2014, and the Commission approved the Application in D.15-04-020 on April 9, 2015. SCE submitted its 2018 – 2020 Application[18] on May 1, 2017, and the Commission approved the Application in D.18-10-052 on October 25, 2018. SCE submitted its 2021 – 2025 Application[19] on October 1, 2022, and the Commission approved the Application in D.18-10-052 on November 30, 2023. SCE is currently executing its 2015 – 2017, 2018 – 2020 and 2021 – 2025 EPIC Investment Plans.

In 2019, the Commission initiated a two-phase rulemaking[20] to determine the future of EPIC. In Phase 1 the Commission determined that EPIC would continue for ten years through 2030, and that each investment period would span five years (2021 – 2025 and 2026 – 2030). Additionally, the Commission authorized the CEC to continue its EPIC administrator role.[21] In Phase 2 of the rulemaking, the Commission determined that the Utilities should continue their roles as EPIC Administrators, along with the CEC.[22] SCE (along with PG&E and SDG&E) filed their respective EPIC 4 Investment Plans, covering 2021 – 2025, on October 1, 2022.[23] Per D.23-04-042, the EPIC Program Administrators are to file annual reports on April 30 of each year, via a Tier 2 Advice Letter that follow the outline in Appendix C.[24]

b) **EPIC Program Components**

The Commission limited SCE's triennial investment applications in the EPIC Program to TD&D projects, per D.12-05-037 and reiterated in D.21-11-028. The Commission defines TD&D projects as installing and operating pre-commercial technologies or strategies at a scale sufficiently large, and in

---

[16] A.12-11-004.
[17] A.14-05-005.
[18] A.17-05-005
[19] A.22-10-001.
[20] R.19-10-005.
[21] D.20-08-042.
[22] D.21-11-028.
[23] A.22-10-001.
[24] D.23-04-042, OP8.

conditions sufficiently reflective of anticipated actual operating environments, to enable appraisal of the operational and performance characteristics and the associated financial risks.[25]

   For administration of their EPIC 1-3 Portfolios, the IOUs successfully utilized the joint IOU framework developed for the 2012 – 2014 cycle (EPIC 1) and enhanced for the 2015 – 2017 (EPIC 2) and 2018 – 2020 (EPIC 3) cycles with updated strategic initiatives to support the latest key drivers and policies. This included the following four program categories: (1) energy resources integration, (2) grid modernization and optimization, (3) customer-focused products and services, and (4) cross-cutting/foundational strategies and technologies. SCE's 2012 – 2014, 2015 – 2017, and 2018 – 2020 Investment Plans proposed projects for each of these four areas, focusing on the ultimate goals of promoting greater reliability, lowering costs, increasing safety, decreasing greenhouse gas emissions, and supporting adoption of low-emission vehicles and economic development for ratepayers.

   For the EPIC 4 Investment Plan, the IOUs coordinated their respective EPIC 4 Plans to use the same structure that the CEC's EPIC 4 Investment Plan applied to technology demonstration areas. Furthermore, IOU administrators have followed the Commission's guidance to file at the Initiative level. Thus, SCE's EPIC 4 Investment Plan was organized under three Strategic Objectives: (1) Create a More Nimble Grid to Maintain Reliability as California Transitions to 100 Percent Clean Energy, (2) Increase the Value Proposition of Distributed Energy Resources to Customers and the Grid, and (3) Guide California's Transition to a Zero-Carbon Energy System that is Climate-Resilient and Meets Environmental Goals. Within these Strategic Objectives, SCE has proposed six Strategic Initiatives, which are specific opportunities and/or challenges: T&D Foundational Technologies, T&D Situational Capabilities, Energy Management Foundational Technologies, Energy Management Situational Capabilities, Vulnerabilities, Threats and Hazard Reduction, and Digital Transformation. In addition, SCE described Research Topics which consider potential project activities in these areas. In 2024, SCE launched five new projects that support EPIC 4's Strategic Objectives, Strategic Initiatives, and Research Topics, and SCE plans to launch more during 2025.

---

[25]   D.12-05-037, OP3.B.

As CPUC looks ahead to EPIC 5, CPUC has identified five Strategic Goals: (1) Transportation Electrification, (2) Distributed Energy Resource Integration, (3) Building Decarbonization, (4) Achieving 100 Percent Net Zero Carbon and the Coordinated Role of Gas, and (5) Climate Adaptation.[26]

SCE values the opportunity to continue playing a critical role as an EPIC administrator for EPIC 5, and looks forward to the opportunity, to align the EPIC 5 Investment Plan with these Strategic Goals, as well as with expected Strategic Objectives.

These Goals are supported by CPUC Proceedings.[27] SCE aims to align its projects with CPUC proceedings. For example, Table 1 shows how SCE's active EPIC projects, from EPIC 2, EPIC 3 and EPIC 4, align with the proceedings that contributed to the EPIC 5 Strategic Goals:

Table 1: Alignment of SCE's Active EPIC Projects with CPUC Proceedings

Proceedings and Description	CPUC EPIC 5 Goals	Active SCE EPIC Projects
R.23-12-008 Transportation Electrification Policy and Infrastructure R.22-07-005 Advance Demand Flexibility Through Electric Rates R.21-06-017 Modernize the Electric Grid for a High Distributed Energy Resources Future R.18-12-006 Development of Rates and Infrastructure for Vehicle Electrification R.24-01-018 Establish Energization Timelines	1. Transportation Electrification	**EPIC 3** • Distributed Plug-In Electric Vehicle Charging Resources • Next Generation Distribution Automation III • Service and Distribution Center of the Future • Smart City Demonstration • Vehicle-to-Grid Integration Using On-Board Inverter **EPIC 4** • Swift Electrification of Transit (SET) • Stability Improvement with DERs (SIDER)

---

[26] D.24-03-007, OP 1.

[27] EPIC Strategic Workshop Process, Kick-Off Workshop. March 19, 2024, https://epicpartnership.org/strategicobjectives.html

Proceedings and Description	CPUC EPIC 5 Goals	Active SCE EPIC Projects
R.24-01-017 California Renewables Portfolio Standard Program R.22-11-013 Distributed Energy Resource Program Cost-Effectiveness Issues, Data Access and Use, and Equipment Performance Standards R.22-07-005 Advance Demand Flexibility Through Electric Rates R.21-06-017 Modernize the Electric Grid for a High Distributed Energy Resources Future R.20-05-003 Continue Electric Integrated Resource Planning and Related Procurement Processes R.19-09-009 Microgrids Pursuant to Senate Bill 1339 and Resiliency Strategies R.18-07-003 California Renewables Portfolio Standard Program R.17-07-007 Streamlining Interconnection of Distributed Energy Resources and Improvements to Rule 21	2. Distributed Energy Resource Integration	**EPIC 3** • Advanced Technology for Field Safety (ATFS) • Beyond Lithium-ion Energy Storage Demo • Control and Protection for Microgrids and Virtual Power Plants • Distributed Plug-In Electric Vehicle Charging Resources • Next Generation Distribution Automation III • Smart City Demonstration • Storage-Based Distribution DC Link • Vehicle-to-Grid Integration Using On-Board Inverter **EPIC 4** • Flexible Alternating Current System (FACS) • ML-Augmented Digital Simulation (MAD-S) • Quantum Networking • Swift Electrification of Transit (SET) • Stability Improvement with DERs (SIDER)
R.22-07-005 Advance Demand Flexibility Through Electric Rates R.19-01-011 Building Decarbonization	3. Building Decarbonization	**EPIC 2** • System Intelligence and Situational Awareness Capabilities **EPIC 3** • Next Generation Distribution Automation III • SA-3 Phase III Field Demonstrations • Service and Distribution Centers of the Future Smart City Demonstration • Vehicle-to-Grid Integration Using On-Board Inverter • Wildfire Prevention & Resiliency Technology Demonstration **EPIC 4** • Flexible Alternating Current System (FACS) • ML-Augmented Digital Simulation (MAD-S) • Quantum Networking • Stability Improvement with DERs (SIDER)

Proceedings and Description	CPUC EPIC 5 Goals	Active SCE EPIC Projects
R.20-05-003 Continue Electric Integrated Resource Planning and Related Procurement Processes R.20-01-007 Long-Term Gas System Planning	4. Achieving 100 percent Net Zero Carbon and the Coordinated Role of Gas	**EPIC 2** • System Intelligence and Situational Awareness Capabilities **EPIC 3** • Advanced Technology for Field Safety (ATFS) • Beyond Lithium-ion Energy Storage Demo • Next Generation Distribution Automation III • SA-3 Phase III Field Demonstrations • Storage-Based Distribution DC Link **EPIC 4** • Flexible Alternating Current System (FACS) • ML-Augmented Digital Simulation (MAD-S)
R.18-04-019 Strategies and Guidance for Climate Change Adaptation	5. Climate Adaptation	**EPIC 3** • Advanced Comprehensive Hazards Tool • Advanced Technology for Field Safety (ATFS) • Smart City Demonstration • Wildfire Prevention & Resiliency Technology Demonstration **EPIC 4** • ML-Augmented Digital Simulation (MAD-S) • Quantum Networking

As described in Table 2 and in the Project Status Reports in Section 4 b), SCE's active EPIC projects also align with EPIC's Mandatory Guiding principle to provide ratepayer benefits, defined as: (1) improving safety, (2) increasing reliability, (3) increasing affordability, (4) improving environmental sustainability, and (5) improving equity, all as related to California's electric system.[28]

Table 2: Alignment of SCE's Active EPIC Projects with EPIC Mandatory Guiding Principle

SCE's EPIC Projects	Components of EPIC Guiding Principle				
	Improve Safety	Increase Reliability	Increase Affordability	Improve Environmental Sustainability	Improve Equity
EPIC 2					
System Intelligence and Situational Awareness Capabilities	X	X	X	X	
EPIC 3					

---

[28]   D.21-11-028 at OP 2 and at Appendix A.

SCE's EPIC Projects	Components of EPIC Guiding Principle				
	Improve Safety	Increase Reliability	Increase Affordability	Improve Environmental Sustainability	Improve Equity
Advanced Comprehensive Hazards Tool	X	X		X	
Advanced Technology for Field Safety (ATFS)	X	X	X	X	
Beyond Lithium-ion Energy Storage Demo		X	X	X	X
Control and Protection for Microgrids and Virtual Power Plants		X		X	
Distributed Plug-In Electric Vehicle Charging Resources		X	X	X	
Next Generation Distribution Automation III	X	X	X	X	X
SA-3 Phase III Field Demonstrations	X	X	X		
Service and Distribution Center of the Future	X	X	X	X	
Smart City Demonstration		X	X	X	X
Storage-Based Distribution DC Link		X	X	X	
Vehicle-to-Grid Integration Using On-Board Inverter		X		X	X
Wildfire Prevention & Resiliency Technology Demonstration	X	X		X	X
EPIC 4					
Flexible Alternating Current System (FACS)	X	X	X	X	X
ML-Augmented Digital Simulation (MAD-S)	X	X	X		
Quantum Networking	X	X			
Swift Electrification of Transit (SET)		X	X	X	X
Stability Improvement with DERs (SIDER)	X	X		X	

c) Coordination

The Utility EPIC Administrators met regularly to discuss the items mentioned above, coordinate investment plan activities, and plan and coordinate joint stakeholder workshops and the annual joint public symposium. Moreover, SCE held regular collaborative meetings with the CEC to help further coordinate the respective investments plans.

The EPIC Administrators collaborated throughout 2024 on the execution of the 2015 – 2017 (EPIC 2), 2018 – 2020 (EPIC 3) and 2021 – 2025 (EPIC 4) Investment Plans. Specific examples of the Administrators' coordination include the following in-person events: the EPIC 4 Wave 1 Project Workshop (March 27, 2024), where SCE publicly presented EPIC 4 projects together with another IOU, the Joint Utilities EPIC Workshop (August 6, 2024) and the 2024 EPIC Symposium (October 28, 2024).

Furthermore, SCE successfully established and ran a Technical Advisory Board (TAB), open to all interested parties, to discuss Vehicle to Grid (V2G) areas of interest to support the EPIC 3 project Vehicle-to-Grid Integration Using On-Board Inverter (V2G), GT-18-0015. As part of the V2G project, SCE worked with standards organizations to help advance relevant standards, working with industry to demonstrate and validate methods to ensure successful implementation.

SCE is also a member of the vPAC (Virtual Protection Automation and Control) Alliance, which aims to accelerate the creation of a standards-based, open, interoperable, and secure architecture. SCE actively contributes to multiple working groups within the alliance to develop a set of specifications for virtualized protection automation & control.

Following these successful collaborations, and on request from other administrators and partners, SCE is looking forward to expanding the use of TABs to other topic areas to collaborate in support of projects by all EPIC Administrators.

SCE also engages with the broader community. SCE's EPIC 4 Investment Plan aims to incorporate the CPUC Environmental Social Justice (ESJ) Action Plan, the Distributed Energy Resources (DER) Action Plan, and federal Justice 40 elements into its project design and execution. Highlights of SCE's plan to work with our communities include:

- Create an overarching EPIC Community Advisory Board made up of grassroots stakeholders who will advise SCE on siting and community benefits opportunities and provide input on project design and investment plans,

- Implement processes to integrate equity and access features into individual projects,

- Seek to site field use case projects in disadvantaged communities that will most benefit from the project and work to incorporate measurable community benefits into success measures,

- Seek to incorporate local education, job training, internships and/or procurement opportunities into the project that benefit the adjacent or greater community, and

- Host project initiation workshops to create awareness and opportunities to work with the community.

SCE is particularly pleased with the EPIC Community Advisory Board, where SCE invited CBOs to prove feedback on SCE's EPIC projects as paid panelists. The goal is to create a partnership where CBOs offer advice and work with SCE to advance EPIC projects and SCE shares its knowledge about the electricity industry, the regulatory process, and other areas of interest to the Panel. SCE presents projects to the Panel over multiple iterations, across project life cycles, to best identify ways that projects can meet community needs and most efficiently share how communities can participate in the benefits of EPIC projects. The Panel is an integral part of SCE's plan to deliver CPUC's goal for EPIC 4 Investment Plans to dedicate at least 25 percent of technology demonstration and deployment (TD&D) funds toward projects located in and benefitting disadvantaged communities and at least 10 percent of TD&D funds toward projects located in and benefitting low-income communities.[29]

Finally, SCE continues to support the Policy + Innovation Coordination Group (PICG) database and provides quarterly updates on its ongoing EPIC projects to the PICG database website (www.epicpartnership.org).

---

[29] D.23-04-042, OP 2.

d) Transparent and Public Process/CEC Solicitation Activities

In 2024, SCE hosted and supported numerous public workshops to make its activities transparent in EPIC. SCE launched its EPIC 4 projects with a public workshop on March 27, 2024. SCE supported the Joint Utilities Workshop, together with the other EPIC Administrators, on August 6, 2024, and then supported the CEC's Annual EPIC Symposium held in-person for the first time since the pandemic on October 28, 2024.

SCE supported numerous parties applying for CEC EPIC funding in 2024. A total of 43 requests for Letters of Support (LOS) and Letters of Commitment (LOC) were received from a diverse array of parties including private vendors, universities, and national laboratories, showing interest in partnering on their bids for CEC projects. Of these 43 requests, SCE provided LOS for 30 and LOC for 13. Six LOC and five LOS were approved by the CEC, and another 15 are still actively being reviewed for award.

For SCE, a LOS typically supports the premise of a project. In some instances, it will infer technical advisory support if the project is awarded to the recipient and the party and SCE come to a mutual understanding of what advisory support will be required.

A LOC includes the early financial and/or technical support in the event that the project is awarded to the recipient. All public stakeholders continue to have the opportunity to participate in the execution of the Investment Plans by accessing SCE's EPIC website, www.sce.com/regulatory/epic, where they can view SCE's Investment Plan Applications, request a LOS or LOC, and directly contact SCE with questions pertaining to EPIC.

3. Budget

a) Authorized Budget

(1) 2012 – 2014 Investment Plan

Table 3: 2012 – 2014 Authorized EPIC Budget (Annual)

2012 – 2014 (Jan 1 – Dec 31)	Administrative	Project Funding	Commission Regulatory Oversight Budget
SCE Program	$1.3M	$11.9M	$0.33M[30]
CEC Program	$5.3M	$47.7M	

(2) 2015 – 2017 Investment Plan

Table 4: 2015 – 2017 Authorized EPIC Budget (Annual)

2015 – 2017 (Jan 1 – Dec 31)	Administrative	Project Funding	Commission Regulatory Oversight Budget
SCE Program	$1.4M	$12.5M	$0.35M
CEC Program	$5.6M	$50M	

(3) 2018 – 2020 Investment Plan

Table 5: 2018 – 2020 Authorized EPIC Budget (Annual)

2018 – 2020 (Jan 1 – Dec 31)	Administrative	Project Funding	Commission Regulatory Oversight Budget
SCE Program	$1.5M	$13.6M	$0.38M
CEC Program	$6.0M	$54.4M	

(4) 2021 – 2025 Investment Plan

Table 6: 2021 – 2025 Authorized EPIC Budget (Annual)

2021 – 2025 (Jan 1 – Dec 31)	Administrative	Project Funding	Commission Regulatory Oversight Budget
SCE Program	$1.5M	$13.6M	$0.38M
CEC Program	$6.0M	$54.4M	

Table 7: 2021 – 2025 Authorized EPIC Project Budget by Strategic Initiative (Total 5-year Budget))

Strategic Objectives	Strategic Initiative	Amount
Create a More Nimble Grid to Maintain Reliability as California Transitions to 100% Clean Energy	T&D Foundational Technologies	$10.5M[31]
	T&D Situational Capabilities	$13.3M[32]
	Energy Management Foundational Technologies	$14.0M[33]

---

[30] Advice Letter, 2747-E, p. 6.

[31] A.22-10-001.

[32] *Ibid.*

[33] *Ibid.*

Increase the Value Proposition of Distributed Energy Resources to Customers and the Grid	Energy Management Situational Capabilities	$13.2 M[34]
Inform California's Transition to an Equitable, Zero-Carbon Energy System that is Climate-Resilient and Meets Environmental Goals	Vulnerabilities, Threats and Hazard Reduction	$8.7M[35]
	Digital Transformation	$8.4M[36]
Total		**$68.1M[37]**

b) Commitments/Encumbrances

(1) 2012 – 2014 Investment Plan

As of December 31, 2024, SCE has committed $470,070[38] and encumbered $0 of its authorized 2012 – 2014 program budget.

(2) 2015 – 2017 Investment Plan

As of December 31, 2024, SCE has committed $843,637 and encumbered $580,114 of its authorized 2015 – 2017 program budget.

(3) 2018 – 2020 Investment Plan

As of December 31, 2024, SCE has committed $9,431,542 and encumbered $5,557,907 of its authorized 2018 – 2020 program budget.

(4) 2021 – 2025 Investment Plan

As of December 31, 2024, SCE has committed $39,000,000 and encumbered $0 of its authorized 2021 – 2025 program budget.

(5) CEC & CPUC Remittances

For CEC remittances, SCE remitted $6,082,800 for program administration, and $42,813,104 for encumbered projects during calendar year 2024.

For CPUC remittances, SCE remitted $380,175 in calendar year 2024.

---

[34] *Ibid.*

[35] *Ibid.*

[36] *Ibid.*

[37] *Ibid.*

[38] SCE is reviewing these commitments.

c) Fund Shifting Above 15% between Strategic Initiatives

As of December 31, 2024, SCE does not have any pending fund shifting requests and/or approvals between Strategic Initiatives for the 2012 – 2014, 2015 – 2017, 2018 – 2020 or 2021 – 2025 investment plans.

d) Uncommitted/Unencumbered Funds

As of December 31, 2024, SCE has no uncommitted/unencumbered funds for the 2012 – 2014, 2015 – 2017 or 2018 – 2020 investment plans. SCE has $29,251,325 of uncommitted project funds and $68,051,325 of unencumbered project funds for the 2021 – 2025 Investment Plan (EPIC 4).

4. Projects

a) High Level Summary

SCE provides a summary of project funding for SCE's 2012 – 2014, 2015 – 2017, 2018 – 2020 and 2021 – 2025 Investment Plans; please refer to Table 8, Table 10, Table 12, and Table 14, respectively. In accordance with the Commission's directives,[39] SCE has prepared Final Project Reports for each completed project and included them in the Annual Reports according to the years completed.

(1) 2012 – 2014 Investment Plan

As of December 31, 2024, SCE has expended $38,642,227 on program costs. No projects from the 2012 – 2014 Investment Plan remain in execution as of December 31, 2024. Table 8 summarizes the 2012 – 2014 Investment Plan projects by program category and completion year.

Table 8: 2012 – 2014 Investment Plan Summary

1. Energy Resources Integration

Three projects funded
• <u>Completed in 2016</u>: Distribution Planning Tool
• <u>Completed in 2018</u>:
  • Distributed Optimized Storage (DOS) Protection & Control Demonstration and
  • Advanced Voltage and VAR Control of SCE Transmission Project

---

[39] D.13-11-025, OP14.

2. Grid Modernization and Optimization
Five projects funded • <u>Cancelled in 2014</u>: Superconducting Transformer[40] • <u>Completed in 2015</u>: Portable End-to-End Test System • <u>Completed in 2016</u>: Dynamic Line Rating • <u>Completed in 2017</u>: Next Generation Distribution Automation, Phase 1 • <u>Completed in 2020</u>: Substation Automation 3 (SA-3), Phase 1

3. Customer Focused Products and Services
Three projects funded • <u>Completed in 2015</u>: Outage Management and Customer Voltage Data Analytics Demonstration • <u>Completed in 2016</u>: Submetering Enablement Demonstration • <u>Completed in 2017</u>: Beyond the Meter: Customer Device Communications Unification and Demonstration

4. Cross-Cutting/Foundational Strategies and Technologies

Five projects funded
• <u>Completed in 2015</u>: Cyber-Intrusion Auto-Response and Policy Management System
• <u>Completed in 2016</u>: Enhanced Infrastructure Technology Report
• <u>Completed in 2017</u>:
  • State Estimation Using Phasor Measurement Technologies Project
  • Deep Grid Coordination Project (otherwise known as the Integrated Grid Project)
• <u>Completed in 2019</u>: Wide Area Management and Control

Total Projects Funded: 16 Total Authorized Project Budget: $37,656,998 [41] Total Project Spend: $37,087,185 Total Funding Committed: $470,070 Total Encumbered: 0 *Note: Due to intrinsic variability in TD&D projects, amounts shown are subject to change*

Table 9 below summarizes SCE's 2024 administration expenses:

Table 9: 2012 – 2014 Investment Plan Administration Expenses

Total Authorized Budget:	$1,855,002[42]
Total Cumulative Cost:	$1,555,042
Total 2024 Cost:	$0

---

[40] SCE cancelled the Superconducting Transformer project in Q2, 2014. Please refer to the project's status update in Section 4 for additional details.

[41] D.12-05-037, as updated by D.13-11-025. Includes $2,045,000 transfer from administrative funds to project funds.

[42] 2012-2014 EPIC I Administrative Budget is $3,812,000. SCE Program Management transferred $1,956,998 from the Administrative to the Project Budget, reducing the Authorized Budget to $1,855,002.

(2) 2015 – 2017 Investment Plan

As of December 31, 2024, SCE has expended $39,437,223 [43] on

program costs. Table 10 below summarizes the current status of SCE's EPIC 2 projects:

Table 10: 2015 – 2017 Investment Plan Summary

1. Energy Resources Integration

Three projects funded
• Cancelled in 2016:
  • Bulk System Restoration under High Renewables Penetration project
  • Series Compensation for Load Flow Control project
• Cancelled in 2017: Optimized Control of Multiple Storage Systems

2. Grid Modernization and Optimization
Six projects funded • Completed in 2017: Advanced Grid Capabilities Using Smart Meter Data • Completed in 2018: Proactive Storm Impact Analysis Demonstration • Completed in 2019: Versatile Plug-in Auxiliary Power System • Completed in 2020: Dynamic Power Conditioner • Completed in 2022: Next-Generation Distribution Equipment & Automation, Phase 2 • Currently In Execution: System Intelligence and Situational Awareness Capabilities
3. Customer Focused Products and Services

Three projects funded
• Completed in 2018:
  • DC Fast Charging
  • Integration of Big Data for Advanced Automated Customer Load Management
• Completed in 2019: Regulatory Mandates: Submetering Enablement Demonstration, Phase 2

4. Cross-Cutting/Foundational Strategies and Technologies
One project funded • Completed in 2021: Integrated Grid Project II
Total Projects Funded: 13 Total Authorized Project Budget: $37,504,200 [44] Total Project Spend: $36,080,449 Total Funding Committed: $843,637 Total Encumbered: $580,114 *Note: Due to intrinsic variability in TD&D projects, amounts shown are subject to change*

Table below summarizes SCE's 2024 administrative expenses.

---

[43] SCE's cumulative project expenses amounted to $36,080,449. SCE's cumulative administration expenses amounted to $3,356,774. These totals include SCE labor and overheads. As a result, SCE expended a total of $39,437,223 on program costs.

[44] D.15-04-020, Ordering Paragraph 1 -- Appendix B, Table-5, p. 7.

Total Authorized Budget:	$4,190,400[45]
Total Cumulative Cost:	$3,356,774
Total 2024 Cost:	$199,458

(3) 2018 – 2020 Investment Plan

As of December 31, 2024, SCE has expended $28,511,963[46] on

program costs. Table 12 below summarizes the current status of SCE's EPIC 3 projects.

Table 12: 2018 – 2020 Investment Plan Summary

1. Energy Resources Integration
Two projects funded

- <u>Completed in 2023</u>: Distributed Energy Resources Dynamics Integration Demonstration
- <u>Currently in Execution</u>: Smart City Demonstration

2. Grid Modernization and Optimization
Six projects funded

- <u>Cancelled in 2020</u>: Power System Voltage and VAR Control Under High Renewables Penetration
- <u>Hold/Deferred in 2020</u>: Distribution Primary & Secondary Line Impedance Project
- <u>Currently in Execution</u>:
  - Beyond Lithium-ion Energy Storage Demo
  - SA-3, Phase III Field Demonstrations
  - Storage-Based Distribution DC Link
  - Next Generation Distribution Automation III project

3. Customer Focused Products and Services
Four projects funded

- <u>Completed in 2024</u>
  - Control and Protection for Microgrids and Virtual Power Plants
  - Distributed PEV Charging Resource
- <u>Currently in Execution</u>:
  - Service and Distribution Centers of the Future; and
  - Vehicle-to-Grid Integration Using On-Board Inverter

4. Cross-Cutting/Foundational Strategies and Technologies
Seven projects funded

- <u>Cancelled in 2019</u>: Energy System Cybersecurity Posturing
- <u>Hold/Deferred in 2021</u>: Advanced Data Analytics Technologies (ADAT)
- <u>Completed in 2021</u>: Distributed Cyber Threat Analysis Collaboration (DCTAC)
- <u>Completed in 2022</u>: Cybersecurity for Industrial Control Systems

---

[45] *Ibid.*

[46] SCE's cumulative project expenses amounted to $24,542,563. SCE's cumulative administration expenses amounted to $3,969,400. These totals include SCE labor and overheads. As a result, SCE expended a total of $28,511,963, on program costs.

• Completed in 2024: Advanced Comprehensive Hazards Tool
• Currently in Execution:
• Advanced Technology for Field Safety (ATFS); and
• Wildfire Prevention & Resiliency Technology Demonstration
Total Projects Funded: 19
Total Authorized Project Budget: $40,830,795 [47]
Total Project Spend: $24,542,563
Total Funding Committed: $9,431,542
Total Encumbered: $5,557,907
Due to intrinsic variability in TD&D projects, amounts shown are subject to change

Table 13 below summarizes SCE's 2024 administrative expenses for the 2018 – 2020 investment plan.

Table 13: 2018 – 2020 Investment Plan Administration Expenses

Total Authorized Budget:	$4,562,100 [48]
Total Cumulative Cost:	$3,969,400
Total 2024 Cost:	$362,550

(4) 2021 – 2025 Investment Plan

As of December 31, 2024, SCE has expended $10,796[49] on program

costs. Table 14 below summarizes the current status and funding of SCE's EPIC 4 projects.

Table 14: 2021 – 2025 Investment Plan Summary

1. **T&D Foundational Technologies**	**Total Initiative Funding**
One project funded • Currently in Execution: Quantum Networking	$10,500,000[50]
2. **T&D Situational Capabilities**	**Total Initiative Funding**
One project funded • Currently in Execution: Flexible Alternating Current System (FACS)	$13,500,000[51]

---

[47] D.18-01-008, at p. 38.

[48] D.18-01-008, at p. 38.

[49] SCE's cumulative project expenses amounted to $4,698. SCE's cumulative administration expenses amounted to $6,098. These totals include SCE labor and overheads. As a result, SCE expended a total of $10,796, on program costs.

[50] A.22-10-001.

[51] *Ibid.*

3. Energy Management Foundational Technologies	Total Initiative Funding
One project funded • Currently in Execution: Flexibility Improvement with DERs (FIDER)	$14,000,000[52]
4. Energy Management Situational Capabilities	**Total Initiative Funding**
One project funded • Currently in Execution: Swift Electrification of Transit (SET)	$13,200,000[53]
5. Vulnerabilities, Threats, and Hazard Reduction	**Total Initiative Funding**
No projects funded	$8,651,325[54]
6. Digital Transformation	**Total Initiative Funding**
One project funded • Currently in Execution: ML-Augmented Digital Simulation (MAD-S)	$8,400,000[55]
Total Projects Funded: 5 Total Authorized Project Budget: $68,051,325[56] Total Project Spend: $4,698 Total Funding Committed: $39,000,000 Total Encumbered: $0 *Due to intrinsic variability in TD&D projects, amounts shown are subject to change*	

Table 15 below summarizes SCE's 2024 administrative expenses for the 2018 – 2020 investment plan.

---

[52] *Ibid.*

[53] *Ibid.*

[54] *Ibid.*

[55] *Ibid.*

[56] D.21-11-028, Appendix B Table 3, at p. B3.

Table 15: 2021 – 2025 Investment Plan Administration Expenses

Total Authorized Budget:	$7,605,500 [57]
Total Cumulative Cost:	$6,098
Total 2024 Cost:	$6,098

b) Project Status Report

The descriptions of the project objectives and scope reflect the proposals filed in the respective EPIC Investment Plans,[58] while the project status information reflects the progress through 2024.

(1) 2012 – 2014 Investment Plan Projects

1. Integrated Grid Project – Phase 1

Investment Plan Period:	Assignment to Value Chain:
1st Triennial Plan (2012 – 2014)	Grid Operation/Market Design

Objective & Scope

The project will demonstrate, evaluate, analyze, and propose options that address the impacts of high distributed energy resources (DER) penetration and increased adoption of distributed generation (DG) owned by consumers directly connected to SCE's distribution grid and on the customer side of the meter. This demonstration project is in effect the next step following the Irvine Smart Grid Demonstration project. Therefore, this project focuses on the effects of introducing emerging and innovative technology into the utility and consumer end of the grid to account for this increase in DER resources. This scenario introduces the need for the utility (SCE) to assess technologies and controls necessary to stabilize the grid with increased DG adoption, and more importantly, consider possible economic models that would help SCE adapt to the changing regulatory policy and GRC structures.

This value-oriented demonstration informs many key questions that have been asked:

- What is the value of distributed generation and where is it most valuable?
- What is the cost of intermittent resources?
- What is the value of storage and where is it most valuable?
- How are DER resources/devices co-optimized?
- What infrastructure is required to enable an optimized solution?
- What incentives/rate structure will enable an optimized solution?

Schedule

---

[57] *Ibid.*

[58] The EPIC 1 Investment Plan Application (A.)12-11-004 was filed on November 1, 2012. The EPIC 2 Investment Plan A.14-05-005 was filed on May 1, 2014. The EPIC 3 Investment Plan A.17-05-005 on May 1, 2017. The EPIC 4 Investment Plan A.22-10-001 on October 3, 2022.

Q2 2014 – Q4 2017
Status
The final project report is complete, was submitted with the 2017 Annual Report, and is available on PICG's public EPIC website.

2. Regulatory Mandates: Submetering Enablement Demonstration

Investment Plan Period	**Assignment to Value Chain**
1st Triennial Plan (2012 – 2014)	Demand-Side Management
Objective & Scope	
On November 14, 2013, the Commission voted to approve the revised Proposed Decision (PD) Modifying the Requirements for the Development of a Plug-In Electric Vehicle Submetering Protocol set forth in D.11-07-029. The investor-owned utilities (IOUs) are to implement a two phased pilot beginning in May 2014, with funding for both phases provided by the EPIC. This project, Phase I of the pilot will (1) evaluate the demand for Single Customer of Record submetering, (2) estimate billing integration costs, (3) estimate communication costs, and (4) evaluate customer experience. IOUs and external stakeholders will finalize the temporary metering requirements, develop a template format used to report submetered, time-variant energy data, register Submeter Meter Data Management Agents and develop a Customer Enrollment Form, and finalize MDMA Performance Requirements. The IOUs will also solicit a 3rd party evaluator to evaluate customer experience.	
Schedule	
Q1 2014 – Q1 2017	
Status	
The final project report is complete, was submitted with the 2016 Annual Report, and is available on PICG's public EPIC website.	

3. Distribution Planning Tool

Investment Plan Period	**Assignment to Value Chain**
1st Triennial Plan (2012 – 2014)	Distribution
Objective & Scope	
This project involves the creation, validation, and functional demonstration of an SCE distribution system model that will address the future system architecture that accommodates distributed generation (primarily solar photovoltaic), plug-in electric vehicles, energy storage, customer programs (demand response, energy efficiency), etc. The modeling software to be used allows for implementation of advanced controls (smart charging, advanced inverters, etc.). These controls will enable interaction of a residential energy module and a power flow module. It also enables the evaluation of various technologies from an end-use customer perspective as well as a utility perspective, allowing full evaluation from substation bank to customer. This capability does not exist today. The completed model will help SCE demonstrate, communicate, and better respond to technical, customer and market challenges as the distribution system architecture evolves.	
Status	

The final project report is complete, was submitted with the 2016 Annual Report, and is available on PICG's public EPIC website.

4. Beyond the Meter: Customer Device Communications, Unification and Demonstration (Phase II)

Investment Plan Period	Assignment to Value Chain
1st Triennial Plan (2012 – 2014)	Demand-Side Management
Objective & Scope	
The Beyond the Meter (BTM) project will demonstrate the use of a DER management system to interface with and control DER based on customer and distribution grid use cases. It will also demonstrate the ability to communicate near-real time information on the customer's load management decisions and DER availability to SCE for grid management purposes. Three project objectives include: 1) develop a common set of requirements that support the needs of a variety of stakeholders including customers, distribution management, and customer program; 2) validate standardized interfaces, functionalities, and architectures required in new Rule 21 proceedings, IOU Implementation Guide, and UL 1741/IEEE 1547 standards; 3) collect and analyze measurement and cost/benefits data in order to inform the design of new tariffs, recommend the deployment of new technologies, and support the development of new programs.	
Status	
The final project report is complete, was submitted with the 2017 Annual Report, and is available on PICG's public EPIC website.	

5. Portable End-to-End Test System

Investment Plan Period	Assignment to Value Chain
1st Triennial Plan (2012 – 2014)	Transmission
Objective & Scope	
End-to-end transmission circuit relay testing has become essential for operations and safety. SCE technicians currently test relay protection equipment during commissioning and routing testing. Existing tools provide a limited number of scenarios (disturbances) for testing and focus on testing protection elements; not testing system protection. This project will demonstrate a robust portable end-to-end toolset (PETS) that addresses: 1) relay protection equipment, 2) communications, and 3) provides a pass/fail grade based on the results of automated testing using numerous simulated disturbances. PETS will employ portable Real-Time Digital Simulators (RTDS's) in substations at each end of the transmission line being tested. Tests will be documented using a reporting procedure used in the Power Systems Lab today, which will help ensure that all test data is properly evaluated.	
Schedule	
Q1 2014 – Q4 2015	
Status	

The final project report is complete, was submitted with the 2015 Annual Report, and is available on PICG's public EPIC website.

6. Voltage and VAR Control of SCE Transmission System

Investment Plan Period	Assignment to Value Chain
1st Triennial Plan (2012 – 2014)	Transmission
Objective & Scope	
This project involves demonstrating software and hardware products that will enable automated substation volt/var control. SCE will demonstrate a Substation Level Voltage Control (SLVC) unit working with a transmission control center Supervisory Central Voltage Coordinator (SCVC) unit to monitor and control substation voltage. The scope of this project includes systems engineering, testing, and demonstration of the hardware and software that could be operationally employed to manage substation voltage.	
Schedule	
Q1 2014 – Q4 2018	
Status	
The final project report is complete, was submitted with the 2018 Annual Report, and is available on PICG's public EPIC website.	

7. Superconducting Transformer (SCX) Demonstration

Investment Plan Period	Assignment to Value Chain
1st Triennial Plan (2012 – 2014)	Distribution
Objective & Scope	
This project was cancelled in 2014. No further work is planned.	
Original Project Objective and Scope:	
SCE will support this $21M American Reinvestment and Recovery Act (ARRA) Superconducting Transformer (SCX) project by providing technical expertise and installing and operating the transformer at SCE's MacArthur substation. The SCX prime contractor is SuperPower Inc. (SPI), teamed with SPX Transformer Solutions (SPX) {formerly Waukesha Electric Systems}. SCE has provided two letters of commitment for SCX. The SCX project will develop a 28 MVA High Temperature Superconducting, Fault Current Limiting (HTS-FCL) transformer. The transformer is expected to be installed in 2015. SCE is supporting this project and is not an ARRA grant sub-recipient. SCE is being reimbursed for its effort by EPIC. SCE's participation in this project was previously approved under the now-defunct California Energy Commission's PIER program.	
Status	
SCE formally cancelled this project in Q3 2014.	

8. State Estimation Using Phasor Measurement Technologies

Investment Plan Period	Assignment to Value Chain
1st Triennial Plan (2012 – 2014)	Grid Operation/Market Design

Objective & Scope
Accurate and timely power system state estimation data is essential for understanding system health and provides the basis for corrective action that could avoid failures and outages. This project will demonstrate the utility of improved static system state estimation using Phasor Measurement Unit (PMU) data in concert with existing systems. Enhancements to static state estimation will be investigated using two approaches: 1) by using GPS time to synchronize PMU data with Supervisory Control and Data Acquisition (SCADA) system data; 2) by augmenting SCE's existing conventional state estimator with a PMU based Linear State Estimator (LSE).

Schedule
Q2 2014 – Q4 2017

Status
The final project report is complete, was submitted with the 2017 Annual Report, and is available on PICG's public EPIC website.

9.   Wide-Area Reliability Management & Control

Investment Plan Period	Assignment to Value Chain
1st Triennial Plan (2012 – 2014)	Grid Operation/Market Design

Objective & Scope	
With the planned wind and solar portfolio of 33% penetration, a review of the integration strategy implemented in the SCE bulk system is needed. The basic premise for the integration strategy is that a failure in one area of the grid should not result in failures elsewhere. The approach is to minimize failures with well designed, maintained, operated, and coordinated power grids. New technologies can provide coordinated wide-area monitoring, protection, and control systems with pattern recognition and advance warning capabilities. This project will demonstrate new technologies to manage transmission system control devices to prevent cascading outages and maintain system integrity.	

Schedule
Q2 2014 – Q1 2019

Status
The final project report is complete, was submitted with the 2019 Annual Report, and is available on PICG's public EPIC website.

10. Distributed Optimized Storage (DOS) Protection & Control Demonstration

Investment Plan Period	Assignment to Value Chain
1st Triennial Plan (2012 – 2014)	Distribution

Objective & Scope	
The purpose of this demonstration is to provide end-to-end integration of multiple energy storage devices on a distribution circuit/feeder to provide a turn-key solution that can cost-effectively be considered for SCE's distribution system, where identified feeders can benefit from grid optimization and variable energy resources (VER) integration. To accomplish this, the project team will first identify distribution system circuits where multiple energy storage devices can be operated centrally. Once a feeder is selected, the energy storage devices will be integrated into	

the control system and tested to demonstrate central control and monitoring. At the end of the project, SCE will have established necessary standards-based hardware and control function requirements for grid optimization and renewables integration with distributed energy storage devices.

A second part of this project will investigate how energy storage devices located on distribution circuits can be used for reliability while also being bid into the CAISO markets to provide ancillary services. This is also known as dual-use energy storage. Initial use cases will be developed to determine the requirements for the control systems necessary to accomplish these goals.

| **Schedule** |
| Q2 2014 – Q4 2017 |

| **Status** |
| The final project report is complete, was submitted with the 2018 Annual Report, and is available on PICG's public EPIC website. |

11. Outage Management and Customer Voltage Data Analytics Demonstration

Investment Plan Period	**Assignment to Value Chain**
1st Triennial Plan (2012 – 2014)	Grid Operation/Market Design
Objective & Scope	
Voltage data and customer energy usage data from the Smart Meter network can be collected and leveraged for a range of initiatives focused on achieving operational benefits for grid operations. Before a full implementation of this new approach can be considered, a demonstration project will be conducted to understand how voltage and consumption data can be best collected, stored, and integrated with grid operations applications to provide analytics and visualization capabilities. Further, Smart Meter outage and restoration event (time stamp) data can be leveraged to improve customer outage duration and frequency calculations. Various stakeholders have identified business needs to pursue more effective and efficient ways of calculating SAIDI (System Average Interruption Duration Index), SAIFI (System Average Interruption Frequency Index), and MAIFI (Momentary Average Interruption Frequency Index) for internal and external reporting. Before a full implementation of this new approach can be considered, a demonstration project will be conducted to understand the feasibility and value of providing smart meter data inputs and enhanced methodology for calculating the Indexes. The demonstration will focus on a limited geography (SCE District or Region) to obtain the Smart Meter inputs to calculate the Indexes and compare that number with the current methodologies to identify any anomalies. A hybrid approach using the Smart Meter-based input data combined with a better comprehensive electric connectivity model obtained from GIS may provide a more efficient and effective way of calculating the Indexes. Additionally, an effort to evaluate the accuracy of the Transformer Load Mapping data will be carried out.	
Schedule	
Q1 2014 – Q4 2015	
Status	
The final project report is complete, was submitted with the 2015 Annual Report, and is available on PICG's public EPIC website.	

12. SA-3 Phase III Demonstration

Investment Plan Period	Assignment to Value Chain:
1st Triennial Plan (2012 – 2014)	Transmission
Objective & Scope	
This project is intended to apply the findings from the Substation Automation Three (SA-3) Phase II (Irvine Smart Grid Demonstration) project to demonstrate real solutions to automation problems faced by SCE today. The project will demonstrate two standards-based automation solutions (sub-projects) as follows: Subproject 1 (Bulk Electric System) will address issues unique to transmission substations including the integration of centrally managed critical cyber security (CCS) systems and NERC CIP compliance. When the project was proposed Subproject 2 (Hybrid) intended to address the integration of SA-3 capabilities with SAS and SA-2 legacy systems. In 2016 SA-3 Hybrid scope was completely dropped from the EPIC SA-3 phase III Demonstration. Furthermore, as part of the systems engineering the SA-3 technical team will demonstrate two automation tools as follows: Subproject 3 (Intelligent Alarming) will allow substation operators to pin-point root cause issues by analyzing the various scenarios and implement an intelligent alarming system that can identify the source of the problem and give operators only the relevant information needed to make informed decisions; and Subproject 4 (Real Time Digital Simulator (RTDS) Mobile Testing) will explore the benefits of an automated testing using a mobile RTDS unit, and propose test methodologies that can be implemented into the factory acceptance testing (FAT) and site acceptance testing (SAT) testing process.	
Schedule	
Q1 2014 – Q4 2020	
Status	
The final project report is complete, was submitted with the 2020 Annual Report, and is available on PICG's public EPIC website.	

13. Next-Generation Distribution Automation

Investment Plan Period	Assignment to Value Chain
1st Triennial Plan (2012 – 2014)	Distribution
Objective & Scope	
SCE's current distribution automation scheme often relies on human intervention that can take several minutes (or longer during storm conditions) to isolate faults, is only capable of automatically restoring power to half of the customers on the affected circuit and needs to be replaced due to assets nearing the end of their lifecycle. In addition, the self-healing circuit being demonstrated as part of the Irvine Smart Grid Demonstration is unique to the two participating circuits and may not be easily applied elsewhere. As a result, the Next-Generation Distribution Automation project intends to demonstrate a cost-effective advanced automation solution that can be applied to the majority of SCE's distribution circuits. This solution will utilize automated switching devices combined with the latest protection and wireless communication technologies to enable detection and isolation of faults before the substation circuit breaker is opened, so that at least 2/3 of the circuit load can be restored quickly. This will improve reliability and reduce	

customer minutes of interruption. The system will also have directional power flow sensing to help SCE better manage distributed energy resources on the distribution system. At the end of the project, SCE will provide reports on the field demonstrations and recommend next steps for new standards for next-generation distribution automation.

| **Schedule** |
| Q1 2014 – Q4 2017 |

| **Status** |
| The final project reports are completed, were submitted with the 2017 Annual Report, and are available on PICG's public EPIC website. SCE has completed an Executive Summary Report that ties the subprojects together, which was submitted with the 2018 Annual Report, and is available on PICG's public EPIC website. |

14. Enhanced Infrastructure Technology Evaluation

Investment Plan Period	**Assignment to Value Chain**
1st Triennial Plan (2012 – 2014)	Distribution

| **Objective & Scope** |
| At the request of internal stakeholders, the project will investigate, demonstrate, and evaluate recommendations for enhanced infrastructure technologies. The project will focus on evaluating advanced distribution sectional poles (hybrid, coatings, etc.), concealed communications on assets, vault monitoring systems (temperature, water, etc.), and vault ventilation systems. Funding is needed to investigate the problem, engineering, demonstrate alternatives, and come up with recommendations. SCE sees the need for poles that can withstand fires, have a better life cycle cost and provide installation efficiencies when compared to existing wood pole replacements. Due to increased city restrictions, there is a need for more concealed communications on our assets such as streetlights (e.g., on the ISGD project, the City of Irvine would not allow SCE to install repeaters on streetlights due to aesthetics). SCE also sees the need for technologies that may minimize premature vault change-outs (avg. replacement cost is ~$250K). At present, SCE does not have the necessary real-time vault data to sufficiently address the increasing vault deterioration issue, nor does SCE utilize a hardened ventilation system that would help this issue by removing the excess heat out of the vaults (blowers last ~ 2 years, need better bearings for blower motors, etc.). |

| **Schedule** |
| Q2 2014 – Q4 2016 |

| **Status** |
| The final project report is complete, was submitted with the 2016 Annual Report, and is available on PICG's public EPIC website. |

15. Dynamic Line Rating Demonstration

Investment Plan Period	**Assignment to Value Chain**
1st Triennial Plan (2012 – 2014)	Transmission
Objective & Scope	

Transmission line owners apply fixed thermal rating limits for power transmission lines. These limits are based on conservative assumptions of wind speed, ambient temperature, and solar radiation. They are established to help ensure compliance with safety codes, maintain the integrity of line materials, and help secure network reliability. Monitored transmission lines can be more fully utilized to improve network efficiency. Line tension is directly related to average conductor temperature. The tension of a power line is directly related to the current rating of the line. This project will demonstrate the CAT-1 dynamic line rating solution. The CAT-1 system will monitor the tension of transmission lines in real-time to calculate a dynamic daily rating. If successful, this solution will allow SCE to perform real-time calculations in order to determine dynamic daily rating of transmission lines, thus increasing transmission line capacity.
Schedule
Q2 2014 – Q1 2016
Status
The final project report is complete, was submitted with the 2016 Annual Report, and is available on PICG's public EPIC website.

16. Cyber-Intrusion Auto-Response and Policy Management System (CAPMS)

Investment Plan Period	Assignment to Value Chain
1st Triennial Plan (2012 – 2014)	Grid Operation/Market Design
Objective & Scope	
Viasat in partnership with SCE and Duke Energy has been awarded a DOE contract (DE-0E0000675) to deploy a Cyber-intrusion Auto-response and Policy Management System (CAPMS) to provide real-time analysis of root cause, extent and consequence of an ongoing cyber intrusion using proactive security measures. CAPMS will be demonstrated in SCE's labs at Westminster, CA. The DOE contract value is $6M with SCE & Duke Energy offering a cost share of $1.6M and $1.2M, respectively.	
Schedule	
Q3 2014 – Q3 2015	
Status	
The final project report is complete, was submitted with the 2015 Annual Report, and is available on PICG's public EPIC website.	

(2) 2015 – 2017 Investment Plan Projects

1. Integration of Big Data for Advanced Automated Customer Load Management

Investment Plan Period	Assignment to Value Chain
2nd Triennial Plan (2015 – 2017)	Demand-Side Management
Objective & Scope	
This proposed project builds upon the "Beyond the Meter Advanced Device Communications" project from the first EPIC triennial investment plan and proposes to demonstrate how the	

concept of "big data"[59] can be leveraged for automated load management. More specifically, this potential project would demonstrate the use of big data acquired from utility systems such as SCE's advanced metering infrastructure (AMI), distribution management system (DMS), and Advanced Load Control System (ALCS), as well as by communicating to centralized energy hubs at the customer level to determine the optimal load management scheme.

Schedule
Q1 2016 – Q4 2018

Status
The final project report is complete, was submitted with the 2018 Annual Report, and is available on PICG's public EPIC website.

2. Advanced Grid Capabilities Using Smart Meter Data

Investment Plan Period	**Assignment to Value Chain**
2nd Triennial Plan (2015 – 2017)	Distribution
Objective & Scope	
This project will examine the possibility of establishing the Phasing information for distribution circuits, by examining the voltage signature at the meter and transformer level, and by leveraging the connectivity model of the circuits. This project will also examine the possibility of establishing transformer to meter connectivity based on the voltage signature at the meter and at the transformer level.	
Schedule	
Q3 2015 – Q1 2017	
Status	
The final project report is complete, was submitted with the 2017 Annual Report, and is available on PICG's public EPIC website.	

3. Proactive Storm Impact Analysis Demonstration

Investment Plan Period	**Assignment to Value Chain**
2nd Triennial Plan (2015 – 2017)	Distribution
Objective & Scope	
This project will demonstrate proactive storm analysis techniques prior to the storm's arrival and estimate its potential impact on utility operations. In this project, SCE will investigate certain technologies that can model a developing storm and its potential movement through the utility service territory based on weather projections. This information and model will then be integrated with the Geographic Information System (GIS) electrical connectivity model, Distribution Management System (DMS), and Outage Management System (OMS) capabilities, along with historical storm data, to predict the potential impact on the service to customers. In addition, this project will demonstrate the integration of near real-time meter voltage data with	

---

[59] Big data refers to information available as a result of energy automation and adding sensors to the grid.

the GIS network to develop a simulated circuit model that can be effectively utilized to manage storm responses and activities and deploy field crews.
Schedule Q3 2015 – Q4 2018
Status The final project report is complete, was submitted with the 2018 Annual Report, and is available on PICG's public EPIC website.

4. Next-Generation Distribution Equipment & Automation - Phase 2

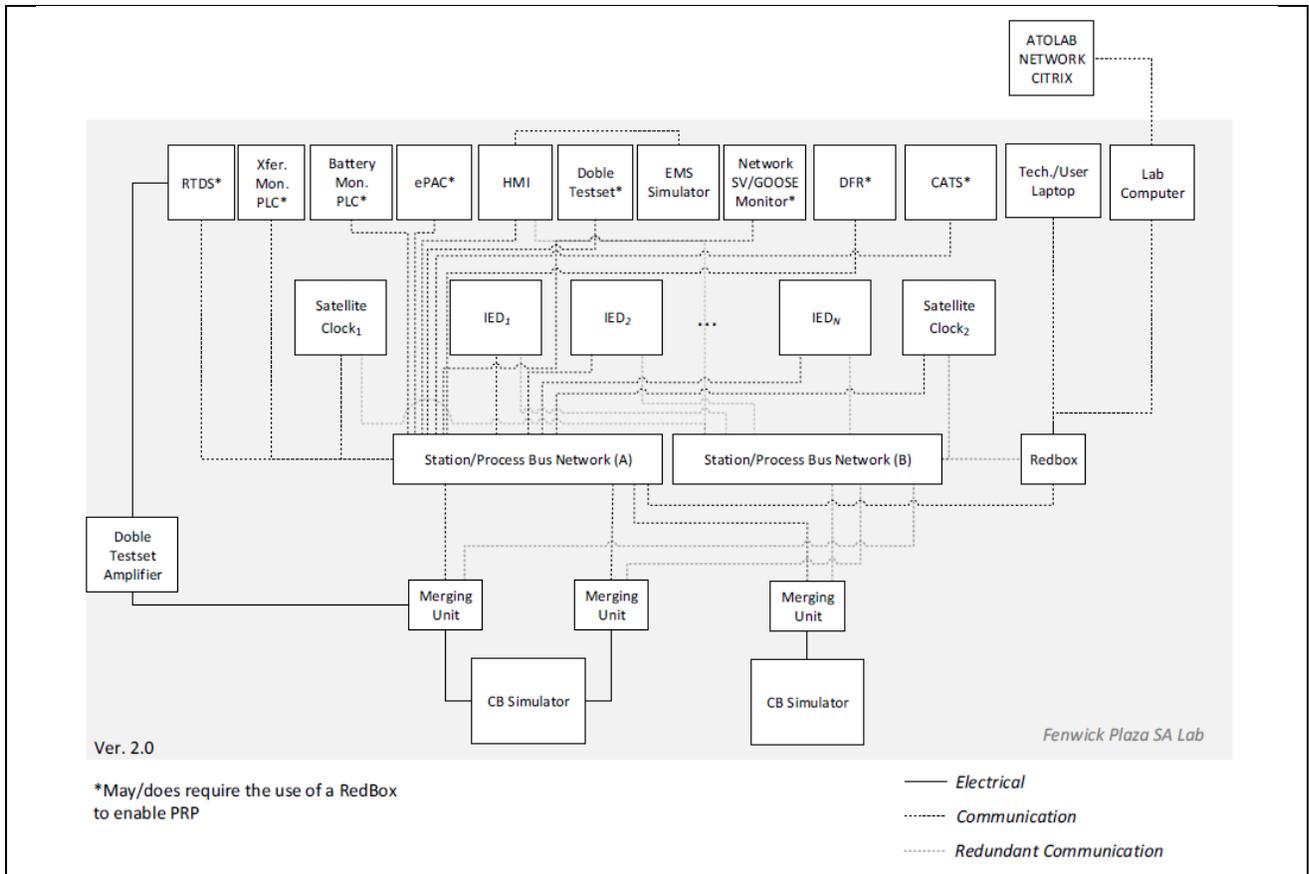| **Investment Plan Period** 2nd Triennial Plan (2015 – 2017)	**Assignment to Value Chain** Distribution
Objective & Scope This project will leverage lessons learned from the Next Generation Distribution Automation – Phase 1 project performed in the first EPIC triennial investment plan period. This project will focus on integrating advanced control systems, modern wireless communication systems, and the latest breakthroughs in distribution equipment and sensing technology to develop a complete system design that would serve as a standard for distribution automation and advanced distribution equipment.	
Schedule Q3 2016 – Q4 2022	
Status The final project report is complete, was submitted with the 2022 Annual Report, and is available on PICG's public EPIC website.	

5. System Intelligence and Situational Awareness Capabilities

Investment Plan Period 2nd Triennial Plan (2015 – 2017)	**Assignment to Value Chain** Distribution
Objective & Scope This project will demonstrate system intelligence and situational awareness capabilities such as high impedance fault detection, intelligent alarming, predictive maintenance, and automated testing. This will be accomplished by integrating intelligent algorithms and advanced applications with the latest substation automation technologies, next generation control systems, latest breakthrough in substation equipment, sensing technology, and communications assisted protection schemes. This system will leverage the International Electrotechnical Commission (IEC) 61850 Automation Standard and will include cost saving technology such as process bus, peer-to-peer communications, and automated engineering and testing technology. This project will also inform complementary efforts at SCE aimed at meeting security and NERC CIP compliance requirements and will test end-to-end digital capabilities between various simulated switchyard gear and protection and control (P&C) devices via a digital interface using IEC 61850 process bus technology. The process bus technology is a key enabler to the digital substation, which will enable SCE to substitute engineering-intensive and costly point-to-point copper signaling wires with a safe,	

standardized optical communication bus (i.e., process bus). In doing so, SCE will remove the copper connections between its high-voltage switchgear and the various P&C devices needed to operate the substation. By retrofitting an existing distribution substation with IEC 61850 process bus technology and replacing protection relays with IEC 61850-capable Intelligent Electronic Devices (IEDs), SCE can develop a more flexible and cost-effective foundation for protecting substations amid increasing renewables and security standards. More specifically, the team anticipates the following potential benefits for its business stakeholders:

- Replacing complex point-to-point copper wires with safe, standardized optical communications will help reduce capital costs associated with the required footprint, construction, and testing of P&C systems.
- An IEC 61850 standard process bus makes it easier to update P&C applications and schemes by updating software configurations rather than hardwired reconfigurations, thereby reducing outage time and maintenance costs (O&M) and providing quicker responses to new protection challenges.
- Potential improvement to field worker safety due to the elimination of electrical connections between high-voltage switchgear and P&C devices—e.g., reducing the potential for inadvertently-opened Current Transformer (CT) circuits.
- The process bus will help increase SCE's understanding of what is occurring within the substation by enabling remote and on-site real-time system monitoring capabilities.
- Data and analysis from devices also enable near real-time asset monitoring, predictive analytics, and health indices to support "just-in-time" asset replacement, increasing the useful lives of capital assets.
- An IEC 61850 standard process bus enables interoperability between devices made by different manufacturers, allowing SCE to choose best-in-breed P&C devices and/or virtual applications.
- Context diagram:

Figure 1: **PHASE 1: Context Diagram for the Fully Digital Substation Project (Field LAB only)**

Ver. 2.0

*May/does require the use of a RedBox
to enable PRP

— Electrical
········· Communication
········· Redundant Communication

Fenwick Plaza SA Lab

Schedule
Q2 2016 – Q3 2025

Project History
A key effort earlier in the project was completion of the Proof of Concept, as described in the
2022 EPIC Annual Report, of IEC 61850-capable relays and other Intelligent Electronic Devices
(IED), merging units (MU), and associated process bus hardware (HW) and software (SW)
components. The purpose of the proof-of-concept project was to demonstrate the benefits and
functionality of using digital technology in a lab environment, while working toward the long-term
goal of implementing a complete IEC 61850 substation automation system. The project aligns with
the safety and grid modernization goals of Southern California Edison (SCE).

In the past year, the following deliverables have been completed in alignment with EPIC 2
Program objectives:
• Lab testing
• Lab testing demonstrations
• Testing results and findings analysis
Upon successful completion of the Fully Digital Substation project, the process bus technology will
be leveraged in future SCE compact sub initiatives.

Looking ahead, the Team will leverage IEC 61850-capable protection relays to replace the
conventional relays. The new relays will be configured using vendor configuration tools that align

to the IEC 61850 standard, enabling interoperability amongst the various vendor IEDs and process bus. The new IEC 61850-capable relays will receive digital monitoring inputs in the form of SMV via the process bus, which they'll used to compute all SCE required protection functions (e.g., instantaneous overcurrent, time overcurrent) and will transmit binary GOOSE messages to the appropriate IED for status and control commands.

Note, the deployment of the lab equipment to a selected SCE substation is not within the scope of IIM-15-0015. Given that the lab equipment is intended to be deployed into a production substation, the lab equipment will be maintained in accordance with the requirements for deployment throughout the project lifecycle. This project will not include any QA or Production phases for the EPIC II project and these phases are out of scope for this project and this document.

Status Update
Accomplishment & Success Stories

The system is designed based on a standard SCE 66/12kV distribution substation arrangement, incorporating 26 protection relays and 33 merging units. In the beginning of the year, the Team completed the lab equipment installation. Immediately after, the Team finalized set up of the IT environment while ensuring appropriate configuration of the network and servers. Once the setup was complete, the Team conducted a thorough cyber risk assessment on all network-connected devices. Finally, the Team performed extensive testing to validate protection and automation schemes, network performance, and PTP time synchronization. These assessments included unit/interface tests, scheme tests, network performance tests, PTP tests, and RTDS tests. All completed work will support the technology transfer process, as well as contribute to the final report that captures overall test findings, lessons learned, and recommendations.

Key Findings and Lessons Learned

- The testing confirmed that fully digital substations using IEC 61850 technology are viable for deployment in live substations. The protection and automation schemes operated as expected with minimal issues.
- Different firmware versions can significantly impact performance and interoperability. Thorough pre-deployment testing is crucial, and a pre-defined firmware update process should be implemented to mitigate risks associated with new firmware releases.
- Digital substations are easy to scale and repeat. To keep them consistent and avoid setup issues, it's best to use standard templates instead of custom configurations.

Customer Benefits
- Potential improvement to field worker safety due to the elimination of electrical connections between high-voltage switchgear and P&C devices—e.g., reducing the potential for inadvertently-opened Current Transformer (CT) circuits.

- The process bus will help increase SCE's understanding of what is occurring within the substation by enabling remote and on-site real-time system monitoring capabilities.
- Data and analysis from devices also enable near real-time asset monitoring, predictive analytics, and health indices to support "just-in-time" asset replacement, increasing the useful lives of capital assets.
- This project will also increase SCE's ability to meet security and NERC CIP compliance requirements. Implementing IEC 61850 process bus technology and IEC 61850-capable Intelligent Electronic Devices (IEDs) will provide SCE more flexible and cost-effective foundation for protecting substations amid increasing renewables and security standards. Elimination of electrical connections between high-voltage switchgear and protection devices improves worker safety.

Industry Advancement
- Upon successful completion of the Fully Digital Substation project, the process bus technology will be leveraged in future SCE compact sub initiatives.
- Vendors were able to build new firmware that fixed the issues discovered during lab demonstration testing.

6. Regulatory Mandates: Submetering Enablement Demonstration – Phase 2

Investment Plan Period	Assignment to Value Chain
2nd Triennial Plan (2015 – 2017)	Demand-Side Management
Objective & Scope	
This project expands on the submetering project from the first EPIC triennial investment plan cycle to demonstrate plug-in electric vehicle (PEV) submetering at multi-dwelling and commercial facilities. Specifically, the project will leverage third party metering to conduct subtractive billing for various sites, including those with multiple customers of record.	
Schedule	
Q4 2015 – Q1 2019	
Status	
The final project report is complete, was submitted with the 2019 Annual Report, and is available on PICG's public EPIC website.	

7. Bulk System Restoration Under High Renewables Penetration

Investment Plan Period	Assignment to Value Chain
2nd Triennial Plan (2015 – 2017)	Transmission
Objective & Scope	
The Bulk System Restoration under High Renewable Penetration Project will evaluate system restoration plans following a blackout event under high penetration of wind and solar generation resources. Typically, the entire restoration plan consists of three main stages; Black Start, System Stabilization, and load pick-up. The Project will be divided into two phases:	

Phase I of the project will address the feasibility of new approaches to system restoration by reviewing the existing system restoration plans and its suitability for higher penetration of renewable generation. It will include a suitable RTDS Bulk Power system to be used in the first stage of system restoration, black start, and it will also include the modeling of wind and solar renewable resources.

Phase II of the project will focus on online evaluation of restoration plans using scenarios created using (RTDS) with hardware in the loop such as generation, transformer, and transmission line protective relays. The RTDS is a well-known tool to assess and evaluate performance of protection and control equipment. This project intends to utilize the RTDS capabilities to evaluate and demonstrate system restoration strategies with variable renewable resources focusing on system stabilization and cold load pick-up. Furthermore, alternate restoration scenarios will be investigated.

After the restoration process is evaluated, tested, and demonstrated in the RTDS Lab environment, we will provide a recommendation to system operations and transmission planning for their inputs to further develop this approach into an actual operational tool.

Status
In December 2016, this project was cancelled by SCE Senior Leadership as a result of an internal organizational change that focused the organization on Distribution System strategic objectives. This was reported in the 2016 EPIC Annual Report.

8. Series Compensation for Load Flow Control

Investment Plan Period	Assignment to Value Chain
2nd Triennial Plan (2015 – 2017)	Transmission

Objective & Scope
The intent of this project is to demonstrate and deploy the use of Thyristor Controlled Series Capacitors (TCSC) for load flow control on series compensated transmission lines. On SCE's 500 kV system in particular, several long transmission lines are series-compensated using fixed capacitor segments that do not support active control of power flow. The existing fixed series capacitors use solid state devices as a protection method and are called Thyristor Protected Series Capacitors (TPSC).

Status
In 2016, it was determined that the deliverables for this project could easily be done via another project that was already in progress. Therefore, SCE ultimately determined that the project should be cancelled. This was reported in the 2016 Annual Report.

9. Versatile Plug-in Auxiliary Power System (VAPS)

Investment Plan Period	Assignment to Value Chain
2nd Triennial Plan (2015 – 2017)	Distribution

Objective & Scope
This project demonstrates the electrification of transportation and vocational loads that previously used internal combustion engines powered by petroleum fuels in the SCE fleet. The

VAPS system uses automotive grade lithium-ion battery technology (Chevrolet Volt and Ford Focus EV) which is also used in notable stationary energy storage projects (Tehachapi 32 MWh Storage).
Schedule   Q3 2015 – Q1 2019
Status   The final project report is complete, was submitted with the 2019 Annual Report, and is available on PICG's public EPIC website.

10. Dynamic Power Conditioner

Investment Plan Period 2nd Triennial Plan (2015 – 2017)	**Assignment to Value Chain** Distribution
Objective & Scope This project will demonstrate the use of the latest advances in power electronics and energy storage devices and controls to provide dynamic phase balancing. The project will also provide voltage control, harmonics cancellation, sag mitigation, and power factor control while fostering steady state operations such as injection and absorption of real and reactive power under scheduled duty cycles or external triggers. This project aims to mitigate the cause of high neutral currents and provide several power quality benefits by using actively controlled real and reactive power injection and absorption.	
Schedule Q3 2016 – Q4 2019	
Status The final project report is complete, was submitted with the 2020 Annual Report, and is available on PICG's public EPIC website.	

11. Optimized Control of Multiple Storage Systems

Investment Plan Period 2nd Triennial Plan (2015 – 2017)	**Assignment to Value Chain** Distribution
Objective & Scope This project aims to demonstrate the ability of multiple energy storage controllers to integrate with SCE's Distribution Management System (DMS) and other decision-making engines to realize optimum dispatch of real and reactive power based on grid needs.	
Status Update In 2017, the goals of this project were found to overlap significantly with those of the EPIC 2 Regional Grid Optimization Demo Phase 2 project (otherwise known as Integrated Grid Project (IGP) Phase 2). This project was then cancelled, and the proposed benefits will be realized through the IGP Phase 2 project.	

12. DC Fast Charging Demonstration

Investment Plan Period	**Assignment to Value Chain**

2nd Triennial Plan (2015 – 2017)	Demand-Side Management
Objective & Scope	
The goal of this project is to demonstrate public DC fast charging stations at SCE facilities near freeways in optimal locations to benefit electric vehicle miles traveled (eVMT) by plug-in electric vehicles (PEVs) while implementing smart grid equipment and techniques to minimize system impact. SCE is actively pursuing several strategic objectives, including optimizing TE fueling from the grid to improve asset utilization. Deploying a limited number of fast charging stations at selected SCE facilities that are already equipped to deliver power at this level (without additional infrastructure upgrade) will support this objective. The project will leverage SCE's vast service territory and its facilities to help PEV reach destinations that would otherwise be out-of-range.	
Schedule	
Q1 2016 – Q1 2018	
Status	
The final project report is complete, was submitted with the 2018 Annual Report, and is available on PICG's public EPIC website.	

13. Integrated Grid Project II

Investment Plan Period	**Assignment to Value Chain**
2nd Triennial Plan (2015 – 2017)	Cross-Cutting/Foundational Strategies & Technologies
Objective & Scope	
The project will deploy, field test, and measure innovative technologies that emerge from the design phase of the Integrated Grid Project (IGP) that address the impacts of distributed energy resources (DERs) owned by both 3rd parties and the utility. The objectives are to demonstrate the next generation grid infrastructure that manages, operates, and optimizes the DERs on SCE's system. The results will help determine the controls and protocols needed to manage DERs, how to optimally manage an integrated distribution system to provide safe, reliable, affordable service and also how to validate locational value of DERs and understand impacts to future utility investments.	
Schedule	
Q3 2016 – Q4 2021	
Status Update	
The final project report is complete, was submitted with the 2021 Annual Report, and is available on PICG's public EPIC website.	

(3) **2018 – 2020 Investment Plan Projects**

1. Cybersecurity for Industrial Control Systems

Investment Plan Period	**Assignment to Value Chain**
3rd Triennial Plan (2018 – 2020)	Grid Operation/Market Design

Objective & Scope
This project will demonstrate the ability to deploy adaptive security controls and dynamically re-zone operational networks while the Industrial Control System (ICS) is either under cyberattack or subject to an increased threat level. The concept of dynamic zoning allows for isolation of threats to certain segments of the ICS and could include both vertical (isolating data flows from SCADA masters to substation endpoints) and horizontal (containing data flows between substations, for example, under a state of manual control when the SCADA master cannot be trusted). Adaptive Controls/Dynamic Zoning (AC/DZ) has the potential to benefit the national grid and ratepayers by bolstering a more resilient and secure grid through the ability to identify and isolate core grid operational functions while under a cyber-attack or incident. The benefits are also cross cutting in that AC/DZ will drive grid operations and cybersecurity together for collaboration to address controls for zones to be defined risk impact mitigations.

Schedule
Q2 2019 – Q4 2022

Status
The final project report is complete, was submitted with the 2022 Annual Report, and is available on PICG's public EPIC website.

2. Advanced Data Analytics Technologies

Investment Plan Period	Assignment to Value Chain
3rd Triennial Plan (2018 – 2020)	Grid Operation/Market Design

Objective & Scope

This project will demonstrate the possibility of using advanced data analytics technologies for Transmission and Distribution (T&D) and customer maintenance. This project will evaluate pattern recognition technologies that are capable of using new and/or existing data sources such as from sensors, smart meters, and supervisory control and data acquisition (SCADA), for predicting or providing alarms on the incipient failure of distribution system assets. These assets would include connectors, transformers, cables, and smart meters.
 	
Use-case Scope
 	
Use supervised machine learning techniques to train, validate, then demonstrate a time-to-failure model on a subset of SCE's distribution transformer installed base. The models will quantify the probability of failure (at the transformer-level) and estimate the remaining useful life (RUL) of distribution transformers.
 	
Business Objective
1. Inputs to the Transformer Asset Class Strategies
    a. Inform risk buy down calculations based on remaining useful life (RUL)
    b. Inform aggregation of like transformers based on level of RUL for decision making
2. Prevent an In-service Failure
    a. Avoid unplanned outage time (reduced CMI, reduce crew OT expense)

    b.   Repair during planned outage (lessen customer impact)

    c.   Avoid catastrophic failure and resulting consequences (damage to customer/public property, safety, surrounding equipment, wildfire ignition)

3. Procurement/Inventory Planning

    a.   Pre-order replacement transformer if there are none in inventory

    b.   Budget planning for future procurement (Inform future GRC Testimony)

Status

This project was deferred in April 2021 to allow consideration of other projects which may offer greater benefits aligned with California and CPUC objectives.

3. Advanced Technology for Field Safety

Investment Plan Period	Assignment to Value Chain
3rd Triennial Plan (2018 – 2020)	Distribution

Objective & Scope

This project will introduce an integrated system that consists of an AR (Augment Reality) wearable, handheld device, communication module, machine vision, generative AI, and digital twin of an underground (UG) vault. The objective is to address the risks posed from grid assets and the environment to the workforce and to enhance the efficiency of the individuals' workflow by introducing an innovative solution that enables them to overcome the challenges they may face in their daily jobs.

The scope of the project includes:

• Utilizing innovative technologies (e.g., machine vision) to collect data to eliminate human error. The captured information would be verified against the backend datasets/digital twin to ensure data accuracy and integrity.

• UG equipment inventory collection will be achieved by camera/sensors on the AR system with GPS mapping/point cloud features to display the location and layout of underground structures. The Team will collect and update the inventory automatically using 3D camera and machine vision. This process will help to maintain an up-to-date digital twin of the UG vault.

• This project enhances situational awareness by integrating necessary SCADA data into workers' field of view such as overlaying the real-time energization status of electrical equipment, the operational status, voltage levels, abnormal conditions, and highlighting any associated warnings, potential hazards, or alerts.

• The 3D digital twin would have detailed information about individual components, such as equipment 3D model, specifications, geographic location, maintenance history, SCADA points, direction of the vault, elbow configurations, switching positions, cable size, nameplates and device IDs of the assets, and a scale to measure clearance distances. etc. This eliminates the need to go through multiple site visits before the job and time-consuming steps to access different layers of information pertaining to any asset/equipment.

- The project will also facilitate live remote assistance between field crews, planners, and Foremen. Using AR-enabled devices, crews in the field can establish a live video feed, allowing remote experts to view the equipment and provide real-time guidance and support.
- The Team is looking to work on interactive access to standards, manuals, and provide voice-enabled assistance by leveraging generative AI technology and Large Language Models.

The successful implementation of this project would aid in utility district planning work orders through increased visibility of the UG (underground) assets, lowering cost of asset management, and improving safety and efficiency of the workforce.

Schedule
Q1 2022 – Q4 2027

Project History
The Advanced Technology for Field Safety (ATFS) project demonstrates the possibility of using new advanced technologies to reduce T&D field crew and customer hazards. The current state of the project is utilizing digital twin and augmented reality to the underground electric vault to improve situational awareness, remote communication, reduce multiple site visits before the work and maintain an up-to-date asset data inventory in 3D model. Planners can plan the work more efficiently with a 1-to-1 scale of the digital twin of the UG vault. The project will also facilitate advanced data collection and storage.

The project was launched in Q4 2019 and re-initiated in Q1 2022. The project team employed a design thinking approach to develop the high-level scope from the end users' perspective.

The drivers for the projects are to improve situational awareness inside the UG vault, create and maintain an up-to-date UG structure inventory, reduce data management cost, easily accessible and voice enabled search of manuals/standards, efficient field data management, as well as access to necessary SAP and SCADA data points.

The identified challenges and workforce concerns that motivated to launch this proof-of-concept project include:
- **Lack of situational awareness inside the UG vault:** Crews not having access to enough tools in the field to have situational awareness while working next to energized assets. This is especially critical in UG systems with limited visibility. Today, access to real-time information is limited and cumbersome.
- **Outdated UG structure Inventory:** Currently, any information that is captured at the site, during structure inventory collection initiatives for specific teams, is not accessible and maintained for any future use of similar types of projects. There is no unified platform representing the UG system accessible to all stakeholders and for various applications.
- **Up to date manuals/standards are hard to access in the field:** A copy of the manuals and standards used by the crews are stored locally in the crews' laptops and are not always up to date. Also, the manuals are not easily accessible during stressful situations in the field where climate conditions could be harsh, noisy, and dark inside the vault.

- **Inefficient field data management:** The existing manual data collection method has a high probability of human errors (e.g., typos) or data loss due to hardcopy paperwork. There's room for innovation to demonstrate tools to efficiently verify SCE internal records as opposed to what they see in the field. Collected data and information is archived after a job is done and is not maintained or kept up to date for later usage.
- **Limited access to backend data:** Workforce needs to go through a lot of paperwork/ hardcopies and time-consuming steps to access diverse types of information pertaining to any asset/equipment. Sometimes all necessary documents might not be collected before visiting the field which may cause delays in the process.
- **Unreliable and unattainable remote communication:** Due to network unavailability in remote areas, communication between the crews, planner and foreman may be disrupted, causing project delays.
- **Lack of access to video/guides:** There's limited field access to tutorials to perform specific tasks in the field. This is especially important since newly trained crews have limited institutional knowledge.

The goals of this project include:
- **Increase safety and situational awareness:** This project is expected to enhance safety by providing the users access to the different layers of data/information for every asset which enhances their situational awareness.
- **Operational Efficiency**: This project enables live remote assistance, enhanced and more efficient data entry, and intuitive and quick access to the latest version of the standards/manuals, overlaying asset information, etc.
- **Improve Reliability:** AR system is expected to minimize the possibility of human error by providing the right tools/information for the users.
- **Reduce data management cost:** This project will study the data collection with AR technology and verify the data discrepancies against backend datasets.

Status Update

Accomplishment & Success Stories
- A prototype project has been completed in Q1 2025 to facilitate project demonstration with internal and external stakeholders.
- An abstract paper has been submitted to the IEEE Digital Twin and Parallel Intelligence conference to highlight the effort and to showcase the completed prototype project.
- The RFP process is currently underway, with the onboarding of preferred vendors anticipated by Q2 2025. During the RFI process, SCE engaged with various vendors and encountered several challenges. One device was found to be uncomfortable for extended use. SCE selected another device, but its user interface was not sufficiently user-friendly, and it is being discontinued. As SCE progressed to the RFP stage, SCE included additional vendors to obtain more comprehensive proposals with various AR technology options.
- The project team finalized the RFI along with the project standards and specifications in Q3 2024.

- The Team will evaluate the prototype project with internal stakeholders in Q1 2025. The Team expects to receive valuable feedback from stakeholders and will integrate the suggestions into the RFP proposal.
- The Team engaged with internal partners and stakeholders to strategize and plan forthcoming procurement initiatives and project enhancement efforts.
- The Team is continuously assessing the schedule and budget to ensure the EPIC 3 project is completed ahead of the planned Q4 2027 deadline.

Challenges or Setbacks
- The project team initially selected an augmented reality (AR) device and successfully completed a prototype project using it. However, the vendor has recently discontinued the production of the device. As SCE is still in the RFP stage, SCE has requested bidders to propose their preferred AR device that aligns with our project objectives. While SCE can demonstrate the project using the initial AR device, SCE will evaluate current industry standards and the best proposals submitted by vendors for the overall final project.

Key Findings and Lessons Learned
- The project scope, benefits, and use cases may evolve in response to the dynamic advancements in current technology. As this project operates at the cutting edge of new technology, SCE must be prepared for potential drawbacks or untested technologies that may present more challenges than benefits.

Customer Benefits
- Improved reliability and efficiency by enabling the integration and utilization of advanced technology.
- Advancements in digitized planning and asset management will reduce the need for commuting and road closures near project sites, thereby minimizing emissions. This enhanced grid utilization will also support California's decarbonization goals.
- Successful implementation of this project, if scaled to a pilot, will eliminate the need for multiple site visits prior to the work order, as planners will have access to the digital twin of the vault to prepare the work order. This will in turn reduce (not eliminate) the costs associated with hiring contractors, obtaining Caltrans traffic control permissions, and removing water from the vault, among other expenses, improving ratepayer affordability.
- Maintaining an up-to-date digital twin inventory of the UG structure, which includes asset information, SAP, and SCADA points, will result in efficient data management, thus increasing operational efficiency.
- Reducing the overall data management cost and work order planning costs for SCE will subsequently benefit Disadvantaged Communities (DACs) in the future.

Anticipated RFPs

The RFP process is currently in progress and expected to be completed by Q2 2025. The activities and deliverables for the RFP include software development of a Digital Twin, Asset Management Tool, and Aid Search Tool, procurement of Augmented Reality devices and Internet of Things edge computing devices, and integration of hardware and software.

Industry Advancement
- The Team lead presented the prototype project at SCE internal lab tours to internal stakeholders, and the Team is going to present at IEEE Digital Twin and Parallel Intelligence conference. This demonstration approach will provide the industry and stakeholders with greater insight into the new technologies being implemented within SCE and illustrate how the overall energy sector can benefit from these advancements.
- Based on the defined use cases of this project, vendors will develop a specialized software tool that utilizes the AR device's information capture capabilities from the UG vault and compares it with the digital twin of the UG vault, thereby ensuring the digital twin remains up to date.
- This project will enhance situational awareness within the UG vault, facilitate live remote assistance between field crews, planners, and foremen, create and maintain an up-to-date UG structure inventory, reduce data management costs, provide easily accessible and voice-enabled search of manuals and standards, ensure efficient field data management, and offer access to essential SAP and SCADA data points. Successful implementation of this project will prove to eliminate the need for multiple site visits prior to the work order, as planners will have access to the digital twin of the vault to prepare the work order. This will reduce costs associated with hiring contractors, obtaining Caltrans traffic control permissions, and removing water from the vault, among other expenses.

4. Storage-Based Distribution DC Link

Investment Plan Period	Assignment to Value Chain
3rd Triennial Plan (2018 – 2020)	Distribution
Objective & Scope	

Objective & Scope

This project will evaluate a battery energy storage system (BESS) that utilizes a novel inverter architecture capable of connecting the BESS to two adjacent circuits (DC Link). By utilizing this new inverter architecture, not only will this DC Link be able to address use cases for which BESS's are traditionally deployed, but it could potentially be used to address use cases that are typically handled using other methods. This inverter architecture can also provide grid operators with a new tool that they can use to perform their job functions and increase grid resiliency and reliability.

Typically, a BESS is deployed to address use cases such as managing line loading to prevent line overload or duct bank temperature violations, optimizing local voltage, and supporting the integration of renewable resources. This demonstration will first determine if it is feasible to provide these benefits to two adjacent circuits. The demonstration will also evaluate the ability

of this DC Link to enhance the operational flexibility currently provided by the feeder parallel/tie switches by allowing the dynamic transfer of power from one circuit to another circuit. A regular parallel/tie switch only allows a fixed amount of power to continuously transfer, whereas a dynamic DC link allows the power transfer to be set to any value, up to the maximum rating of the Power Conversion System and allows the power transfer to dynamically adjust based on the loading of the two circuits.

Schedule

Q3 2019 – Q4 2025

Project History

This project provides ratepayer benefits and supports the EPIC's primary principles of promoting greater reliability, improving affordability, and improving environmental sustainability through the integration of renewables and DERs and by extending the traditional benefits provided by a single energy storage system to two adjacent distribution circuits. This will effectively improve the utilization and value of the storage asset, while enhancing operational flexibility and reliability.

This project also provides progress toward the goal of clean energy transition in California. For example, a storage-based DC Link can increase the hosting capacity of a circuit, allowing additional DER customers to connect. This benefit was documented in a conference paper published at the Cigre Conference in 2023. In addition, the project can improve reliability and resiliency by providing power from an under-utilized circuit to an overloaded circuit. In conjunction with this, the project can defer conventional grid upgrades such as re-conductoring of overhead lines or underground cables.

The Team built on its substantial progress from 2023 into early 2024, but the situation changed in March 2024, when the supplier was unable to solve technical issues with Tie Controller product and decided to discontinue it. The Tie Controller is the power flow control system needed to manage power between 2 circuits.

Technical issues found included:
- Tolerating phase to phase voltage imbalances
- Difficulty in handling fault conditions
- Control system that was not fully developed
- Lack of inductance between circuit and device

As a result of the product being discontinued, the project team closed the original purchase order and pursued other possible DC Link products through an RFI and RFP process in 2024. An RFP was released in November 2024 and will be evaluated in Q1 of 2025

Status Update

Accomplishment & Success Stories
- Investigated possibility/feasibility of increasing the rating of Tie Controller to 17kV in order to accommodate installation on circuits of 16kV rating in SCE territory.
- Developed list of software requirements for Project's main control computer, which included Vivado 2022, Code Composer Studio 12.3.0, and SEL Accelerator software packages.

- Discussed feasibility of utilizing Tie Controller to assist in 4kV cutover projects. The theory for this was to temporarily connect portions of a 4kV circuit to a nearby 12kV circuit through a Tie Controller.
- When the discontinuation of the Tie Controller was announced in early March 2024, the Team investigated the possibility and applications of using a Phase EQ device to continue the DC Link project. After gathering data/feedback from internal Stakeholders, it was ultimately decided not to pursue the Phase EQ.
- Additional lab equipment to support DC Link arrived at our test facility. This included a load interrupter switch, 600 amp switchboard, and 200 amp switch.
- Factory test procedure was submitted.
- Power systems study and a conference paper were completed.
- Fused switches were delivered.
- Emulator to test communications protocols was developed.
- Automation requirements were developed.
- Preliminary graphical user interface screens were developed.
- Developed list of control points and operational procedure.
- Refinement of test procedures was in process.

Challenges or Setbacks
- The main supplier for this project announced that they were discontinuing the Tie Controller in Q1 of 2024, and therefore could not continue with this project. The Team worked with SCE's Supply Management group to determine the pathway to terminate the Contract and settle all financial terms. Without the Tie Controller, the Team had to explore alternatives to continue the DC Link project. The main supplier proposed an alternate product called the "Phase EQ," which, upon evaluation, did not meet the requirements of this project.

Key Findings and Lessons Learned
- A line reactor could be needed when installing the Tie Controller in a lab test environment. The line reactor provides inductance between the voltage source and the Tie Controller itself.
- Impedance impacts the operating zones of the Tie Controller. More resistive is easier to manage. A very low resistance is more difficult to operate with.
- The proposed alternate equipment called Phase EQ was found to have limited benefits at SCE. This was due to: limited type of circuits it could work on (4 wire only), limited to only 12kV or 4kV circuits, limited number of circuits with identified phase imbalances, and limited to circuits with available space that are in built out areas.

Customer Benefits
- When the Tie Controller is used in conjunction with an energy storage system (ESS), it improves the capital utilization of the ESS and also increases the capacity for distributed generators to connect to the circuit.

- The Tie Controller is expected to be able to defer capital upgrades like cable replacement, since cable overloads can be mitigated by transferring some power from the adjacent circuit.

Anticipated RFPs
- An RFP was planned to begin a contract with a new vendor who can continue the DC Link project. The RFP was released in November 2024, with a due date in January 2025.

Industry Advancement
- One area that this project affected within SCE procedures/standards is in the design of the distribution circuit protection system. Specifically, the protection design must be understood prior to installing a Tie Controller on actual circuits. The Tie Controller could influence the relay settings of the main breaker of the substation, which could require an adjustment of the relay settings. Since the Tie Controller is always connected between the two distribution circuits, it is effectively paralleling the circuits at all times. This changes the overall impedance seen by the substation at the feeder head.

4. Smart City Demonstration

Investment Plan Period	Assignment to Value Chain
3rd Triennial Plan (2018 – 2020)	Grid Operation/Market Design

Objective & Scope

The Smart City project will demonstrate a multi-meter microgrid (a.k.a. front-of-the-meter microgrid) that enhances resiliency on a targeted portion of the electric system by optimizing distributed energy resource (DER) portfolios, providing energy and grid support, and keeping essential facilities (e.g., fire station, police station, community center, senior center, water agency, emergency shelter) online in the event of an emergency. The microgrid will enable islanding capability to provide continuous power during an outage, thus limiting reliability impacts associated with planned and unplanned outages.

The project will demonstrate the operation of customer/third-party and utility owned DERs to enhance resiliency and maintain safety/reliability. The project will leverage distributed control architectures and improved planning processes to support city planning, communications, and integration of DERs. The microgrid control system will interface with the Grid Management System (GMS) for safe operation of the microgrid and improved system visibility.

Schedule

Q4 2019 – Q3 2025

Project History

The initial project step was to utilize the laboratory-based Microgrid (MG) testbed created by the EPIC 3 project, GT-18-0018 Control and Protection of Microgrids, which facilitated the design, prototyping, and performance evaluation of all future MG projects.

As noted in the 2023 EPIC Annual Report, the Team completed all Microgrid Control System (MCS) equipment procurement, installation and configuration in SCE's Fenwick Controls Lab and

successfully completed all testing on the MG testbed. The Team also completed installation of Networking and CyberSecurity equipment for the Fenwick Microgrid Lab test bed as well.

A project vendor, Schweitzer Engineering Laboratories (SEL), together with SCE tech leads, certified that the Fenwick Microgrid Lab test bed (MCS) met the contractual requirements, successfully passed final commissioning and site acceptance testing, and successfully demonstrated all use cases.

Status Update

Accomplishment & Success Stories

- In 2024, a Solution Architecture Definition (SAD) document was completed and approved for the Smart City design. The Team completed a Technical Functional Design Specification (FDS) document, and the Team will update it nearer to the beginning of the field deployment stage, when the Team will have more detail surrounding the final field deployment design.
- The Team completed Phase 1 lab testing of a Microgrid Control System (MCS) for deployment in Porterville.
  - A site walk was scheduled and completed at the City of Porterville involving multiple internal teams and the customer. This site walk enabled the project team to finalize the microgrid design which led to the finalization of the conceptual Single Line Diagram (SLD) and the RSCAD model. The RSCAD model could then be provided to the MCS vendor SEL for preparation to start the first phase of project, which is control simulation testing utilizing a RTDS along with the RSCAD model.
  - The MG model software development in RSCAD specific to the City of Porterville MG system was completed (moving forward with generic technical battery specs).
  - Factory Acceptance Testing at the vendor's facility in Pullman, WA was completed in September 2024. MCS vendor SEL provided the Final Code Set configuration files for integrating into our Fenwick Lab. Control Simulation testing (to replicate the FAT testing) in our Fenwick Controls Lab was completed in October 2024.
- Tests at Schweitzer Engineering Laboratories and Fenwick Lab showed the MCS can maintain a healthy Microgrid using DERs, ensuring reliability and resiliency for the SCE Grid and customers. This established a benchmark for designing all future Microgrid deployments across the SCE network.
- The Pomona Microgrid Test Pad design is in progress. 100% Electrical Drawings were completed and approved.
- A construction vendor was selected, and a Bill of Materials (BOM) for the buildout of the Pomona MG Test Pad was received. The switchgear order has been released, and the forecasted timeline is 6 months. The forecast for equipment delivery is March 2025. The forecast to begin Power Hardware in the Loop (HIL) testing is June 2025.
- Procurement of a Solectria PV inverter and an AlsoEnergy PV site controller for the Pomona MG Test Pad was completed.

- The Team began preliminary integration communication testing with equipment that the Team already had in Pomona (MCS devices, AlsoEnergy site controller, PV inverter and PV simulator, GMS simulator).
- Conceptual SLD of Smart City design provided to Distribution Generation Interconnection team for their internal studies review, currently in process.
- Began development of PSCAD model for the Smart City design.
- Discussions with the City of Porterville have resulted in agreement with the Planning Review Committee (PRC), and satisfaction with the substance of the Easement drawings and Pre-Fire Plan. The Customer Agreement document and Easement Agreement are in progress with the City of Porterville and SCE Legal.

Challenges or Setbacks
- The project faced a substantial issue with the need to seek an alternative battery vendor due to legal issues with the awarded battery vendor, thus a new battery vendor RFP had to be submitted.
  - This was done in June 2023, with proposals being received in August 2023.
  - A Battery Energy Storage System (BESS) Vendor was selected and is currently under contract negotiations with SCE Legal.

Key Findings and Lessons Learned
- Due to the success of GT-18-0018 Control and Protection of Microgrids and the initial success of this project, a Project scope change was approved to continue as an EPIC funded project through lab testing. SCE plans then continued to advance to QAS Testing and Field Demonstration as a Capital Pilot project.
- Time synchronization is very important. Many issues the Team observed during Fenwick testing were around time synchronization, such as with the MGC and FEP not coordinating with the synchrowave or with state-based objectives like the economic dispatch or peak shaving modes. Time synchronization alarms should be added to the GMS alarming system.
- MGC controls the BESS automatically to ISOC and VDroop when islanded, regardless of whether it is in manual mode.
- When the POI relay/IED is in a comm alarm state, the DERs will be not take any automatic setpoints from the MGC but will still take HMI local setpoints.

Customer Benefits
- Partnering with the City of Porterville will provide the following benefits once deployed in the field:
  - Provide a front-of-the-meter Microgrid Control System (MCS) supporting essential facilities (e.g., wastewater treatment plant) in the event of grid outages (planned or unplanned)

- Demonstrate operation of customer/third-party and utility-owned distributed energy resources (DERs) to enhance resiliency and maintain safety/reliability
- Evaluate installation of SCE owned energy storage to support microgrid operation, in partnership with SCE's Energy Storage Integration Program for battery energy storage installation.
- Interface with Grid Management System (GMS) for improved system visibility and control

Industry Advancement
- Completed a conference paper that was submitted at the IEEE Power and Energy Society General Meeting (PESGM) 2024 Conference entitled "Power Quality Based Protection for Microgrid and Remote Grid Loads: Type Testing"
  - The Team also created a poster board regarding the completed Power Quality Relay Testing and presented the Team's findings at the conference
- Tests at Schweitzer Engineering Laboratories and Fenwick Lab showed the MCS can maintain a healthy Microgrid using Distributed Energy Resources, ensuring reliability and resiliency for the SCE Grid and customers
  - This established a benchmark for designing all future Microgrid deployments across the SCE network

6. Next Generation Distribution Automation III

Investment Plan Period	Assignment to Value Chain
3rd Triennial Plan (2018 – 2020)	Distribution

Objective & Scope
This project will leverage lessons learned from the Next Generation Distribution Automation II project. It will integrate new FAN wireless radio-to-automation devices and continue to improve control functionalities. It will provide greater situational awareness to allow system operators to manage the grid with higher DER penetration and be ready to support Distribution System Operators (DSOs). It will integrate advanced control systems, modern wireless communication systems, and the latest breakthroughs in distribution equipment and sensing technology to develop a complete system design that would be a standard for distribution automation and advanced distribution equipment. This project will demonstrate technologies that are applicable for both overhead and underground distribution circuits.
Key features of the project include:
- Demonstrating the capability to use an accurate duct bank temperature modeling tool and/or scalable real-time monitoring system. This system would allow for the avoidance of excessive duct bank temperature due to circuit overloading which could lead to premature, catastrophic cable failure. Monitoring of the system could provide better situational awareness to proactively manage circuit loading.
- Exploring improvements upon legacy DNP communications for distribution automation by testing and assessing a standardized communication protocol using IEC 61850 to manage field devices for passive activities including commissioning, updates, retirement, and

cybersecurity patches. The intent is for the results of the testing to enable uniform, accelerated configuration, and enhanced cybersecurity, extending the protocol used by Substation Automation (SA) to the distribution grid.

- Providing a lab-only demonstration of next generation distribution automation controller devices, capable of using the DNP v3 SAV5 secure protocol, to communicate with a lab sandbox Field Device Management Platform (FDMP). The intent of the lab test system is to validate the ability of the next generation controller devices to send/receive messages required for SCE device management.
- Demonstrate cybersecurity enhancement in grid communication by implementing secure routable second editions of protocols, as defined by the latest IEC 61850 standard. This involves using a Key Distribution Center (KDC) to manage key and policy distribution, ensuring secure communication across multiple locations in the grid. The KDC will provide centralized or decentralized management of system enrollment, key distribution, and access control, which is essential for secure multicast communication and encryption of protocol messages.

Schedule
Q3 2019 – Q3 2026

Project History
SCE understood the communication challenges to achieving low latency with IEC61850 protocols. Due to the bandwidth limitations of SCE's legacy wireless communication network, Device Management (DvM) was unable to send configuration settings. The project explored implementation of new technological capabilities, for example, Remote Intelligent Switch (RIS) and their impact on this communication challenge. The new DvM objectives are to remotely send configurations and protection settings to distribution automation field devices to achieve real-time circuit section isolation to improve grid reliability and resiliency.

Additionally, improved cybersecurity is a critical need as utilities move towards an increasingly connected network. This demonstration will test the feasibility of adding encryption to communication between protection devices at substations. The key aspects of effective cybersecurity communication are the distribution of the encryption keys through a Key Distribution Center (KDC) that would act as a centralized authority. Also, without a KDC, it would be difficult to securely manage key and policy distribution for large numbers of multicast groups, which is necessary for secure communication using the second edition of IEC61850 protocols.

The project is in the execution phase and is expected to be completed by Q3 2026.

Status Update
Accomplishment & Success Stories
- For the Device Management lab kit drop 1 and 2, device setups were completed, the application testing was witnessed being conducted off-premises and did not do any on-premises tests, and the test script device version was revised based on the Device Management application capabilities. The project team is performing the knowledge transfer steps for these portions of the project. The project findings will be reported in the NGDA III Final Report when the entire project is completed.

- For the final portion of this project, the Team has completed development of project requirements, a schedule, an overall project plan, a preliminary design for the testing devices, and a lab demonstration setup.
- The Team initiated an RFI to determine devices that support encryption natively, without requiring additional hardware. The RFI responses have been received, and the project team is continuing to evaluate contractors to procure professional drawings and test plans for the project.
- The Team has also met with internal partners to discuss plans for installing equipment in the Substation Automation laboratory.

Challenges or Setbacks
- The project faced substantial issues with software not meeting project requirements.
  - Several vendor device solutions for the next generation Distribution Automation (DA) controller devices, capable of using the DNP3.0 Secure Authentication Ver5 (SAv5) protocol, did not meet the IEEE 1815-2012 DNP3.0 standards. The project team decided to descope this portion of the project. The project findings will be reported in the NGDA III Final Report when the entire project is completed.

Key Findings and Lessons Learned
- Through internal and external discussions with stakeholders, SCE learned that the network encryption has been demonstrated and is fully functional, removing the concern about the viability of the technology when it will be demonstrated in the lab environment. The project team witnessed encrypted communication at the 2024 IEC 61850 Interoperability Testing Event.

Customer Benefits
- The Team identified new sources of customer value by enhancing system reliability and grid hardening through cybersecurity efforts, preventing unauthorized access to substation network traffic.
- The Team quantified the benefits of adopting encryption, which ensures cybersecurity for large substations serving over 500,000 customers, and calculated the financial impact by mitigating unintended outages and associated fines.

Anticipated RFPs
- In Q1 2025, the project team will issue an RFP for professional drawings to wire test equipment on substation racks.
- In Q2 2025, the project team will issue an RFP for test plans to assess system resiliency and for supplemental workers to assist with executing these test plans for the demonstration project.

Industry Advancement

- The project tests new IEC-61850 standard additions for encrypting Routable-GOOSE traffic between substation protection devices. It will push vendors to develop mature firmware supporting encrypted communication, as current devices use Beta firmware.
- This project impacts SCE's access protocols for substation operators, shifting from fixed, site-specific credentials to system credentials updated every 24 hours. Credentials can be revoked and reissued as needed after scheduled work.
- Upon completing the demonstration project, the encryption technology will be implemented at substations using 61850 communications, with a local server managing encryption keys between protection devices.

7. SA-3 Phase III Field Demonstrations

Investment Plan Period	Assignment to Value Chain
3rd Triennial Plan (2018 – 2020)	Transmission

Objective & Scope

The objective of Substation Automation Phase 3 is to successfully demonstrate a modern substation automation system for use in transmission substations by adopting scalable technology that enables advanced functionality to meet NERC CIP compliance and IT cybersecurity requirements. This project aims to provide measurable engineering, operations, and maintenance benefits through improved cybersecurity and reliability for transmission substations. It will also provide interoperability and allow the system to work with relays from multiple vendors, prevent vendor lock-in due to proprietary software and hardware, and assure that SCE has the flexibility to implement the best solution available.

Today, protection relays are dedicated appliances that receive inputs and outputs through hardwired connections. The IEC 61850 standard includes the concept of a process bus. The process bus replaces the hard wire I/O with fiber optic networking technology, thereby eliminating a significant portion of the wiring required for protection and automation systems.

The concept of virtualized protection relays goes one step further and eliminates the physical relay hardware in favor of a virtual environment. The concepts allow the relays to act as software appliances utilizing process bus signals to perform their functionality, similar to the virtualization that is being used on the Common Substation Platform (CSP).

With virtualized relays there are several foreseeable benefits:
- Smaller footprint, simplified design, and reduced cost. Relays within a substation can be consolidated to a limited number of racks thereby reducing the footprint required by a substation control room and simplifying the design process. Additional benefits include reduced hardware cost.
- Faster deployment timelines, seamless failure recovery, and multivendor compatibility. Benefits of current virtualized environments such as redundancy, automated backups, and

automated deployment tools can be utilized to improve engineering, testing and deployment cost and schedules.
- Ease of testing new automation and protection applications. With a virtualized environment, new protection and automation applications can be implemented and tested without the need to physically redesign the system. This redesign will lead to minimal changes to the overall physical environment. Upgrades and transitions to new architectures will require minimal engineering.

This project seeks to form a partnership with relay vendors to demonstrate and evaluate a proof-of-concept system utilizing machine virtualization and process bus technology. The following outcomes are expected from this project:
- Proof of concept hardware and software
- Comprehensive evaluation and testing
- Recommendations for future projects
- All design documents (business requirements, system requirements, test plans, test reports, use cases, etc.)
- Share project lessons learned with industry by presenting at least one technical conference

Schedule
Q3 2019 – Q2 2025

Project History
Substation Automation Phase 3 leverages earlier projects, including projects from the EPIC 1 and EPIC 2 Investment Cycles. The EPIC 1 projects, like Next-Generation Distribution Automation, Phase 1, piloted some of the first stages of fully adopting and integrating IEC61850 into the substation. This included the use of redundant LANs, Parallel Redundancy Protocol, use of VLANs for managing network traffic, use of Precision Time Protocol for time synchronization, and implementing GOOSE and MMS inside the substation. Overall, the network architecture and design has largely influenced preceding projects and lab demonstrations.

EPIC 2 projects like Next-Generation Distribution Equipment & Automation - Phase 2 and previous demonstrations of IEC61850 Process Bus and Sampled Values also heavily influenced design considerations for this project. Components of the system were down selected based on lessons learned and findings from previous work.

The approach to testing and consideration of IEC61850 implementations were also influenced by work from previous projects.

This project expands on previous efforts by further leveraging the benefits of digital communications in substations. This lab demonstration shows that the previous efforts to transition to digital communications in the substation can enable the use of virtualization technologies for protection applications. The use of digital communications between Merging Units and protection relays eliminates the need for individual, proprietary hardware for every protection application. However, the technology for virtualized protection relays must be tested thoroughly to ensure that performance and reliability are maintained. This project aims to prove

that the protection application is reliable and has comparable performance to traditional protection relays.

The benefits from this demonstration and future projects include showing that implementation for the virtual protection relay has the potential to reduce the substation control room footprint size and enable faster construction, maintenance, and commissioning. The virtual protection relay solution offers significant flexibility in the selection of components, which means that utilities can choose vendor solutions that best align with the needs of a specific site or application.

In the past year, the following deliverables have been completed in alignment with EPIC 3 Program objectives:
- Lab testing
- Lab testing demonstrations
- Testing results and findings analysis

Status Update

Accomplishment & Success Stories
- The Team executed a number of test cases on the first VPR system. As this system was more fully developed, the testing performed was more extensive. Testing on system 2 was also performed. The Team collaborated with the system vendors to address issues observed during testing and the Team provided feedback on expected and actual results.
- The Team completed the majority of protection application test cases on system 1 during 2024. The Team received the second system in early 2024 and integrated the system with the existing lab environment.
- The Team evaluated multiple vendor solutions for virtualized protection relays.
- The Team plans to meet with internal partners and stakeholders in a series of sessions to review and discuss project findings, test results, and lessons learned.
- The Team continues to evaluate the gaps and requirements for fully adopting a virtualized protection relay solution and the next steps for a field demonstration or pilot project.
- The Team presented this project at a conference discussing the utility perspective on virtual protection relays and SCE's approach to the lab demonstration design and testing. Additional conference presentations are planned in 2025.

Challenges or Setbacks
- The project faced a substantial issue with maintaining product licensing which was used for the application under test. Issues with licensing resulted in delays to testing as tests could not be executed on the system during a state where a product license had expired.
- The Team mitigated the issue/risk by working with both the protection application vendor and virtualization application vendor to identify possible solutions. The Team also worked internally to identify possible solutions for procuring licenses. While many possible resolutions were explored and exhausted, the impacts from the licensing caused a delay in the test execution phase of this project.

- The Team resolved the issue by procuring additional product licensing, and it has documented the impacts that licensing may have on the survivability and availability of the critical applications.

Key Findings and Lessons Learned
- Throughout 2024, this project's lab testing progressed in demonstrating virtual protection relay systems. The project Team was able to collaborate with internal and external stakeholders to resolve issues identified within the protection application configuration, network configuration, and time synchronization implementation.
- Findings and lessons learned include documenting the differences that exist in the required protection settings between the systems under test and SCE's standard protection devices.
- There were also some network configuration changes made during this testing and settings implemented to allow for redundancy while mitigating possible bridges in the network.

Customer Benefits
- Given that this project is a lab demonstration initiative, field deployment is not within the project scope.
- That said, a successful lab demonstration could provide benefits including those listed about in the Objective & Scope section: (1) smaller footprint, simplified design, and reduced cost, (2) faster deployment timelines, seamless failure recovery, and multivendor compatibility; and (3) ease of testing new automation and protection applications.

Industry Advancement
- The Team presented at Distributech 2024 and the IEEE PES General Meeting 2024.
- The Team is also significantly involved in the vPAC Alliance, as discussed above in Section 2 c), which aims to develop a set of industry specifications for virtualized protection systems.
    - Members of the Team actively contribute to the vPAC Alliance in multiple working groups. Members of the Team have also been participants in the IEEE P21 working group for system architectures supporting virtualization of protection and control.
- The Team has had regular discussions with protection relay vendors. The Team provided updates to vendors on SCE's vision and roadmap for virtualized protection. SCE also collaborates with members of the vPAC alliance to develop industry specifications on virtualized protection automation and control.
- This project is a lab demonstration proof of concept. During the reporting and stakeholder demonstration phase of this project, the Team will share relevant findings and lessons learned with project stakeholders. Many of the findings from this project will relate to future considerations for adopting virtualized protection relays; however, some lessons learned can be useful for design considerations for digital substations which could be implemented as a standard or best practice sooner than virtualized protection application related findings.

8. Distributed Cyber Threat Analysis Collaboration

Investment Plan Period	Assignment to Value Chain
3rd Triennial Plan (2018 – 2020)	Grid Operation/Market Design

Objective & Scope

This project will demonstrate the ability to standardize utility cybersecurity threat analysis by developing a Distributed Cyber Threat Analysis Collaboration framework to conduct local utility collaboration with utility peers and sharing with National analysis centers to support expedient cyber threat feed analysis. This framework will demonstrate the capability to effectively consume internal and external sourcing threat feeds, process them for legitimacy, and identify utility risk impact, and potential response measures through collaboration with utility peers and National analysis centers to validate and verify threats as well as significantly shorten the time needed to respond to a cyber compromise of the electric grid.

Schedule

Q2 2019 – Q4 2021

Status

The final project report is complete, was submitted with the 2021 Annual Report, and is posted on PICG's public EPIC website.

9. Energy System Cybersecurity Posturing (ESCP)

Investment Plan Period	Assignment to Value Chain
3rd Triennial Plan (2018 – 2020)	Grid Operation/Market Design

Objective & Scope

This demonstration will automate the ability to probe the Utility's supervisory control and data acquisition (SCADA) system using an automated probing capability which will enable the system to report back on how it is configured. The ESCP project will engineer a toolset to demonstrate the capability to execute an automated system posture where cybersecurity and regulatory related system attributes will be collected and analyzed via the toolset. It will then demonstrate enhanced network communications situational awareness through a Software Defined Networking (SDN) interface with the capability to support cross cutting operations and cybersecurity analysis.

Status Update

During project planning in 2019, the Team learned that additional research would be required to complete this project. This research is not currently available, nor allowable for the Utilities to conduct under current EPIC requirements. SCE canceled this EPIC project and is looking into alternative funding sources.

10. Distribution Primary & Secondary Line Impedance

Investment Plan Period	Assignment to Value Chain
3rd Triennial Plan (2018 – 2020)	Distribution

Objective & Scope
This project will examine the possibility of establishing primary and secondary line impedance information for distribution circuits by examining the voltage and power signatures at the meter and transformer levels, leveraging a basic connectivity model of the circuits, and utilizing SCADA data. The availability of complete primary line impedance information can improve the accuracy of load flow / distribution state estimation results, greater real-time management of the distribution grid, and greater utilization of capacity within the existing installed infrastructure before requiring new assets.

Status
Due to budget constraints SCE put this project on hold in 2020.

11. Advanced Comprehensive Hazards Tool

Investment Plan Period	**Assignment to Value Chain**
3rd Triennial Plan (2018 – 2020)	Grid Operation/Market Design

Objective & Scope:
This project demonstrates a new and innovative approach to integrate emerging and mature hazard assessment tools. This demonstration will use a centralized data architecture that integrates various types of SCE asset data from non-electric, generation, and grid infrastructure. The project aims to identify vulnerabilities across different types of infrastructure to understand the overall risk to the grid. The project demonstrates hazard scenarios and the impacts of those scenarios to the SCE system.   The project demonstrates a comprehensive natural hazard web application with multi-layer mapping capabilities that provides an integrated, holistic view of hazards in the service territory (e.g., earthquake, flood, fire, and extreme weather events). The application has the ability to conduct risk analysis that allows for asset data to be referenced with hazard exposure and probability of failure or consequence (fragility) to arrive at risk profiles for the assets.   This project integrates: • Various types of asset data from non-electric, generation, and grid infrastructure sources, to provide decision-support on hazard impact and mitigation options before, during, and after a significant event (e.g., extreme weather events, wildfires, and earthquakes, etc.).   • Hazard risk assessment / severity index capabilities allowing a comprehensive assessment of vulnerability and exposure across the service territory.

Schedule:
Q4 2019 – Q1 2024

History of the project
Understanding the sensitivity of specific components of electricity systems and their collective vulnerability to climate and weather hazards is crucial to long-term planning. In the short-term, centralization and effective interpretation and use of decision-making tools and information is critical to prevent or mitigate loss and damage and initiate recovery efforts. Today, "piecemeal" solutions are tailored to individual applications and threats. As such, disparate processes, methods, and models may exist, which may be in conflict and may affect mitigation and recovery

plans in larger incidents and disasters. Centralization and optimization of planning and operations capabilities for hazard mitigation and hazard response capabilities are required to enhance effective responses during these natural hazard events.

Furthermore, this project supports the Commission's Climate Adaptation Rulemaking. As part of the Climate Adaptation Rulemaking, all utilities are required to perform a vulnerability assessment to understand electric system vulnerabilities in the event of hazards brought on by climate change. The tool being demonstrated as part of this project will improve the Commission and SCE's understanding of the electric system's vulnerabilities to natural hazard events by assisting with risk assessments and identifying grid vulnerabilities that can be documented with SCE's future vulnerability assessment filings.

The Final Project Report was submitted and included detailed lessons learned, areas for maturity, and potential synergies with other internal or external efforts.

Status Update
The Team finished the project in early 2024, with very little incremental work in 2024. Thus, what follows below is an overall project review based on achievements reported through the 2023 EPIC Annual Report

Accomplishments & Success Stories
The Comprehensive Hazards Tool (CHaT) successfully integrated hazard assessment tools and consolidated data sources to improve grid vulnerability analysis. Key achievements include:
- Standardizing internal tools for hazard risk assessment.
- Demonstrated capabilities to improve seismic hazard mitigation planning and provide early situational awareness.
- Successfully integrating CHaT software with SCE and 3rd party data for validation and testing.

The Grid Resilience Intelligence Platform (GRIP) demonstrated and tested the GRIP software. Achievements include:
- Performing initial validation with real SCE data in a remotely accessible lab environment by SLAC (Stanford Linear Accelerator Center) researchers.
- Successfully deploying GRIP in the lab environment at SCE for validation and testing.
- Integrating grid infrastructure data for four circuits to perform core testing of functionality.
- Completed initial testing of pole vulnerability and tree fall/vegetation conductor contact.

Challenges or Setbacks
- A setback encountered early in the project occurred when the first selected vendor declined to participate after an extensive negotiation on terms and conditions that would satisfy all party members. The vendor was not comfortable with the terms stated in EPIC Intellectual Property (IP) flowdowns nor in the SCE master software licensing agreements.
- A challenge encountered during project execution was the ability to provide members from the selected vendors access to SCE Critical Energy Infrastructure datasets. This was mitigated by onboarding the individuals who required access to the data. The vendor did not meet the

cybersecurity vendor risk assessment requirements to gain access to the data without onboarding.

- The final challenge related to the maturity of climate-related risk assessment methodologies and models for electric utilities from both industry and academia. Initiatives such as EPRI's Climate READi will provide much needed contributions for this area of knowledge.

GRIP

- The included CYME circuit model to Grid-lab-D Hi-pas converter had to be tested on 14 circuits and modified to integrated asset model information from circuit libraries (conductors, poles, etc.). A few converter issues were identified for CYME 9 Rev 6. Six critical issues were resolved with 100% success rate for all 14 circuits.
- During the initial data integration period from Aug 23 to Dec 23, modifications were made to several thousand code deletions and additions (28,285 additions and 19,374 deletions), to successfully integrate and run all simulation models in the GRIP simulation pipeline. 15 changed files were released and checked into GitHub under release 4.3.3 on December 1, 2023.
- Accessing wind speed data near the location of pole failures was challenging using the USGS National Weather services and internal sources. Access to better weather station locations with historical data was sourced through a weather data service from Synoptic data.

Key Findings and Lessons Learned

- The CHaT tool is effective for seismic studies, but quantifying the impacts of climate and weather on electric utility assets is challenging. Transmission lines, substations, and distribution lines are vulnerable to various weather events. Understanding these vulnerabilities is crucial for long-term planning, especially considering the expected increase in extreme weather. Additional efforts are needed to enhance these capabilities such as multi-hazard events. Multi-hazard events such as atmospheric "blocking" events can cause weather systems to stall, leading to persistent warm, dry, and still conditions when they occur in the summer. Coincidence of high temperatures and low wind events could further limit transmission line capacity. Systems may be further stressed if high temperatures lead to higher loads. Another example is an "atmospheric river" event combined with extreme wind conditions. Distribution poles are prone to failure due to high winds, excessive rainfall and/or flooding.
- GRIP's successful demonstration of data installation and integration into its software platform has significant implications for reducing Public Safety Power Shutoff (PSPS) events. By conducting initial validation tests on pole vulnerability and the potential for vegetation or tree falls, the project is actively working towards refining the criteria for PSPS events. This could lead to more accurate assessments of infrastructure resilience and environmental risks, ultimately decreasing the frequency and duration of power shutoffs necessary to ensure public safety during extreme weather conditions. Ongoing validation efforts aim to further lower PSPS thresholds, enhancing power stability and reliability for communities.

- Analysis of weather data indicates that pole failures were triggered by two distinct wind conditions: a swift escalation in wind velocity within a six-hour period and prolonged exposure to high winds for over 36 hours. A significant number of these failures were localized in a specific region, occurring at wind speeds slightly lower than the thresholds set for wind resistance design. Interestingly, not every instance of pole damage led to power outages, suggesting some redundancies in the power grid infrastructure that prevent service disruptions despite the damage.

Customer Benefits
CHaT
- Enhance grid reliability, lowers costs, and improves safety by informing optimal design and mitigation strategies for natural hazard events.
- Reduce repair frequencies and durations by hardening the grid in high-risk areas.
- Mitigate loss and damage from hazard events, facilitating more efficient recovery efforts.
- With a high likelihood of a major earthquake in Southern California, CHaT could inform earthquake risk mitigation for critical utility assets like substations.
- Improve public and utility worker safety: By improving grid resiliency and response to hazards, CHaT can reduce public exposure to dangerous situations (like wildfires) and lessen the need for workers to operate in hazardous conditions.

GRIP
- Provide opportunities to reduce risk by identifying and replacing high-risk poles.
- Help address challenges posed by high winds in Southern California, such as those experienced in Hawaii, to prevent incidents such as wildfires.
- The benefits of enhancing climate adaptation capabilities are multifaceted. Firstly, it leads to improved reliability and resilience for customers, ensuring consistent service despite varying climate conditions. Secondly, creating a lab partnership environment allows for the practical validation of DOE-funded technologies using real-world data. This not only accelerates innovation but also ensures that the technologies developed are aligned with the actual needs and challenges faced by customers, thereby providing tangible benefits.

Industry Advancement
CHaT
- Reducing outage numbers, frequency, and duration: The tool's hazard mitigation and response capabilities can enhance grid resiliency and enable faster responses to hazards, potentially reducing or eliminating prolonged power outages and equipment damage.
GRIP
- Collaboration with experts: Meetings were held with industry experts in wind simulation modeling to introduce them to GRIP's capabilities.
- Publication: An article about the work completed by SCE and the consultant is being reviewed for publication, highlighting the project's achievements.

- Continued validation and improvement of the GRIP platform are being conducted under the US Dept of Energy Grid Modernization Lab Consortium project, with results expected in the 4th quarter of 2024. The test environment setup funded by EPIC will remain in place for continued validation by SLAC, with lower support from SCE once additional validation data is provided.
- Shared benefits and potential with other utilities facing similar risks worldwide.

12. Vehicle-to-Grid Integration Using On-Board Inverter

Investment Plan Period 3rd Triennial Plan (2018 – 2020)	Assignment to Value Chain Distribution
Objective & Scope The project will assess and evaluate new interconnection requirements, Vehicle-to-Grid (V2G) related technologies and standards, and utility and third-party controls to demonstrate how V2G direct current (V2G-DC) and V2G alternating current (V2G-AC) capable EVs and EV chargers can discharge to the grid under grid-managed structures and methods and be used to support resiliency during grid outages. The project will assess and evaluate, in a laboratory environment, V2G-AC Rule 21 consistent interconnection processes, proposed SAE and UL standards, and the function of automaker OEM battery/inverter systems to support vehicle-grid integration (VGI) services, and integration of project 3rd party aggregators with SCE's Grid Management System (GMS)/DER Management System (DERMS).	
Schedule Q1 2020 – Q3 2025	
Project History The Team completed demonstration with a vehicle OEM in 2023. Integration testing of the V2G-AC demonstration was completed in Q4 of 2023 as per the 2023 Annual Report. Type testing and end-to-end testing commenced in 2024 following the necessary updates to the vehicle and EVSE. While this testing was originally planned to be finished in 2024, issues with the Distributed Energy Resource Management System (DERMS) connection resulted in this being pushed out to 2025. In 2023, the project was negotiating with two vendors for the V2G-DC demonstration. However, these vendors elected not to participate in the project. In 2024, another two vendors were identified as replacements; negotiations are continuing with one of the vendors for a V2G-DC demonstration in Q1 2025. The findings of the demonstrations will help inform the necessary standards updates to provision for vehicle-to-grid export (e.g., UL 1741 SC) and changes to Rule 21 as those updates are finalized and published. In addition, the demonstrations will support transportation electrification as well as reliability efforts by demonstrating the ability to manage vehicle charging, helping to minimize the impact of higher Plug-in Electric Vehicle (PEV) penetration on existing energy infrastructure.	

Status Update

Accomplishment & Success Stories

- The report for a vehicle OEM demonstration was finalized.
- V2G-AC Demonstration
    - Successful demonstration of the SAE J3072 authorization to discharge process.
    - Partial demonstration of end-to-end communications using a non-SCE DERMS. To be re-tested with SCE DERMS as needed.
    - Testing expected to conclude Q1 2025 following SCE DERMS integration and delivery of V2H test equipment.
- V2G-DC Demonstration
    - DC EV charger and aggregator vendor finalized in Q4 2024. Ongoing negotiations regarding procurement and integration of aggregator server with SCE DERMS.

Challenges or Setbacks

- Integration of this project with the SCE DERMS has uncovered several issues related to the aggregator to DERMS connection, particularly with the ability to dispatch controls end to end.
    - When SCE DERMS was not yet available, this was mitigated in a limited capacity through the usage of a third-party DERMS. However, re-testing with SCE DERMS is necessary to fully verify end-to-end communications between SCE and the DER (the vehicle).
    - The DERMS vendor is pausing the addition of new features temporarily to focus on resolving priority issues in the current DERMS release.
- For some tests, the onboard inverter failed to comply with the issued control.
    - For these tests, communication logs from the EV were collected to verify that the correct 2030.5 payloads were received by the EV. This at least confirmed that end-to-end communications were working, even if the vehicle did not respond to the control as expected.

Key Findings and Lessons Learned

- The aggregator server used as part of the test setup is the second aggregator client to be connected to the SCE DERMS. The various issues identified and resolved as this aggregator connection was configured will assist in building out the process(es) for connecting future aggregator clients as DERMS is rolled out.

Customer Benefits

- Lessons learned from the demonstration will help SCE develop customer programs related to vehicle-to-grid export.
- The management of EV charge/discharge can enable higher PEV penetration on existing infrastructure.

Industry Advancement

- V2G Technology Advisory Board

- • Presented at the V2G Forum in San Diego, CA in May 2024.
  - • Presented at the V2G Forum in Detroit, MI in October 2024.
- • Presentation on the V2G EPIC Demonstration to DER industry representatives at SunSpec Member Annual Meeting in San Diego, CA in December 2024.
- • Continued support for UL 1741 SC, SAE J3072, SunSpec IEEE 2030.5 profile for SAE J3072, and V2G related CPUC Proceedings (Rule 21, High DER, etc.)
- • Engagement with SCE's GMS/DERMS group to support the implementation of DERMS.

13. Distributed Plug-In Electric Vehicle Charging Resources

Investment Plan Period	Assignment to Value Chain
3rd Triennial Plan (2018 – 2020)	Distribution

Objective & Scope:

This project will demonstrate PEV fast charging stations with integrated energy storage that can be used to control the grid system impact of fast charging, allowing more of them to be accommodated for a particular cost, and also to respond to grid needs as distributed energy resources when not in use to charge a vehicle. Fast charging units currently demand 25 to 125 kW or more each, and the load cannot be planned or scheduled. This demand is expected to climb to 350 kW or more as advertised by vehicle and charging system suppliers. This intermittent and unpredictable high demand could affect utility planning and could also challenge high deployment of such systems due to their low load factor and potentially alarming bill impacts to customers under current tariffs.

Combining fast charging systems with energy storage can result in a higher load factor, while still providing satisfactory service to customers. The size of such storage systems, along with power components, will determine their effectiveness in a particular duty cycle.

This is demonstrated in the demands on the system from customers in the real world, which this project will show; the demands on such energy storage systems may be met by the capabilities of used batteries. These measures increase the likelihood of higher numbers of such stations becoming operational. Integrated energy storage provides reliability in the case of grid events – transient or otherwise – and improves charging service in the evolving modern system of increased renewable and distributed generation. This project will demonstrate the reliability improvement of such systems subject to grid events.

Schedule:

Q4 2019 – Q1 2025

History of the project

SCE's project addresses the sizing of Energy Storage Systems (ESS) tailored for fast charging and grid asset applications. The plan also outlined the utilization of energy storage to perform peak shaving, which could work in tandem with fast charging to increase customer adoption of EVs and potentially reduce costs. This strategy aimed to minimize the risk of oversizing the distribution system as well as increase the use of clean, renewable energy resources.

Additionally, the plan included a responsive approach to grid events to minimize customer impact and provided support for distribution circuit Volt/VAR (volt-ampere reactive) control.

Given that the growth in EV adoption ultimately will create a market for used batteries, the project also initially planned to assess the advantages and disadvantages of utilizing second-life batteries for integrated ESS applications. When the project was conceived, SCE had identified a major automotive manufacturer as a partner and source of second-life batteries. However, the manufacturer shifted its focus to battery recycling and could not provide SCE with these batteries. SCE attempted to find another source of second-life batteries, preferably integrated with direct current (DC) fast charging but was unsuccessful. Thus, this work was removed from the project.

Specific project objectives included:
- Establish specifications for the integrated fast charger and energy storage systems.
- Obtain test data measuring performance of close-coupled fast charging/energy storage systems for functions including, but not limited to:
  - Peak shaving,
  - Demand Response (DR) program participation, and
  - Volt/VAR support.
- Create internal knowledge transfer deliverables, including reports, presentations, and workshops.
- Create external knowledge transfer deliverables, including at least one conference presentation and workshops.

2024 Status Update:
Accomplishment & Success Stories
- The project was able to successfully integrate the Charge Management System (CMS) with an ESS and a DC fast charger (DCFC). The CMS was able to dispatch the ESS and curtail charging on the DCFC.
- The project used a cloud-based server to simulate the Distributed Energy Resources Management (DERMS) and send IEEE 2030.5 commands to the CMS.
- The base use case of Load Leveling was successfully demonstrated using both vehicle emulators and a real EV. The use of the EV emulator allowed the Team to shorten the test cycle significantly. The Team also made several mitigation efforts and was able to move up the testing completion date to November 2024, and move the final completion date to Q1 2025 instead of Q3 2025.
- The CMS received a simulated demand response (DR) command and was able to curtail the demand at the point of interconnection (POI) by either dispatching the ESS, curtailing charging, or both.
- The project team was able to successfully demonstrate Volt-Watt, Volt-Var, and power factor regulation by sending the appropriate IEEE 2030.5 commands and curves to the CMS. The

CMS was able to coordinate the activities of the ESS and the DCFC to ensure uninterrupted charging while responding to grid events.

- The Team met with internal partners to discuss how the lessons learned, the use cases developed, and the test procedure developed can be applied to other projects, such as the EPIC 3 projects Service and Distribution Centers of the Future and potentially Smart City Demonstration.
- The Team presented this project at the CIGRE (Conseil International des Grands Réseaux Electriques, or The International Council on Large Electric Systems) Grid of the Future conference in Raleigh, NC in November of 2024 on the subject of "Managing High-Demand EV Fast Charging through Smart Charging and Energy Storage Integration."

Challenges or Setbacks
- The project encountered significant challenges due to delays in procuring power systems. SCE faced difficulties in acquiring necessary equipment promptly, largely due to the epidemic.
- The Team mitigated the impacts of the worldwide manufacturing and logistical shortage by amending test procedures and was able to complete testing on schedule.

Key Findings and Lessons Learned
- Through internal and external discussions with stakeholders, the Team developed test procedures that can be adapted to future microgrid / EV charge management testing.
- The Team demonstrated that the IEEE 2030.5 commands can be used with an integrated EVSE and ESS to manage loads and perform grid support.
- Second-life batteries remain scarce, constraining the expansion of energy storage systems. Integrating rapid charging technology with these systems can boost load factors, ensuring reliable customer service. The size of these storage units and their power components will dictate their efficiency within a specific duty cycle.

Customer Benefits
- The Team demonstrated that the incorporation of energy storage could enable DC fast charging to be implemented in areas with limited electrical infrastructure capability, as in disadvantaged communities, or could defer upgrades typically needed for fast charging projects.
- The Team demonstrated that the ESS could improve grid reliability and power quality without impacting vehicle charging. This could improve service in impacted areas and provide another revenue stream to offset the costs of the ESS and charging system.

Industry Advancement
- The Team presented at the CIGRE Grid of the Future Conference.
- The Team was able to implement load leveling, demand response, and setting various voltage support functions using the current implementation of IEEE 2030.5.

- The Team's experience is currently being used to provide SCE's Transportations Services as it continues with its efforts to electrify the Edison fleet.

14. Service and Distribution Centers of the Future

Investment Plan Period 3rd Triennial Plan (2018 – 2020)	Assignment to Value Chain Distribution
Objective & Scope The objective of this project is to evaluate the ability to fully electrify a fleet service center with building electrification technologies (e.g., space and water heating), Electric Vehicle Supply Equipment (EVSE) and employee charging while managing any associated impacts to the local grid system. The results could inform future efforts to electrify other service centers, while also supporting commercial customer electric vehicle loads. This project will demonstrate an advanced SCE service center with electrified utility crew trucks, together with employee workplace charging, connected to a local service area with high penetration of distributed solar generation and plug-in electric vehicles. The electrification of transportation at the service center will be conducted in a way that not only does not adversely impact the local system but also interacts with the system using DER and vehicle-grid integration (VGI) technology to ensure reliable and stable service for both the service center and local area. This project will demonstrate electrified utility trucks and utility and workplace EVSE with advanced VGI communications and controls to receive and respond to both demand response (direct) and SCE grid (dynamic) signals to both ensure reliable charging and to support local grid stability. The vehicle systems, when not driving, can be used as grid assets and respond directly to support system voltage and stabilize demand. This two-front approach leverages the operating characteristics of both fleet trucks (charge at night) and employee vehicles (charge in the morning). This project will examine the benefits of moving toward electric transportation for SCE's fleet and many customers' fleets. Installing charging infrastructure to fully electrify those fleets can reach constraints, as large numbers of heavy-duty vehicles will need very high power and energy capacity, approaching 30 MW per location in some cases. Challenges are not only at the individual depot with deploying electrical infrastructure to support the vehicles and manage costs but also in surrounding areas. SCE has grid reliability and modernization plans in process which will provide new tools for managing the system. Meanwhile, high demand for PV distributed generation, energy storage, and concentrated EV charging can result in local challenges adjacent to and connected to the fleet base. In addition, SCE's Clean Power Pathway identifies the need for general electrification of facilities and full integration of energy management tools. This project will demonstrate a fleet service center supporting large EV charging demands, supporting elements such as energy storage, PV, and controlled (V1G) and bidirectional (V2G) EV

charging, and electrified space and water heating, all controlled by an innovative site energy management system to maintain safe and reliable operation and minimize costs. The location will be in a disadvantaged community (Dominguez Hills, Compton, CA). The site will facilitate connection to SCE's grid data and operational management systems to enable local distribution system support.

Schedule

Q4 2019 – Q2 2026

Project History

The procurement of the NOMAD mobile battery in Q4 2024 helped move the project into the next phase to prepare for lab testing. This project is moving forward with plans to begin lab testing in Pomona, CA in Q2 2025.

In addition, another EPIC 3 project, Control and Protection for Microgrids and Virtual Power Plants, helped in establishing the baseline configurations and test bed on which Service and Distribution Centers of the Future is built. Findings during testing will help future efforts when testing Service and Distribution Centers of the Future in the lab environment. Performance testing of Control and Protection for Microgrids and Virtual Power Plants also helped in confirming that the hardware platform chosen would be sufficient for Service and Distribution Centers of the Future testing.

Continued coordination with vendor and partners has led to the development of the Technical FDS. The Technical FDS will be used to establish the test plan which should be approved in Q2 2025.

The ratepayers will benefit in the longer run by having functional Microgrid Control Systems on the grid because this will increase reliability. With the adoption of this technology, Microgrid Controllers can be used to maximize resiliency and energy distribution to points of need (i.e., grid support, emergency vehicle charging), power distribution of utility energy storage systems, Distributed Energy Resources (DERs), large scale EV charge management systems, and to allow for increased efficiency of power distribution.

Status Update

Accomplishment & Success Stories

- Successful specification and procurement of a new Mobile Battery Energy Storage System (MBESS).
- Determined system requirements to integrate Building Management System (BMS) to the Microgrid Control System (MCS). This was a new integration for SCE.
- Created RTDS model of system for testing in lab environment, including SCADA simulation.
- Developed a Utilization Guide to share with all vendors integrating with the MCS (EVSE, MBESS, BMS). Its purpose was to provide stakeholders with a comprehensive overview of the system's components, operational modes, and interaction mechanisms, thereby ensuring a unified understanding and facilitating effective collaboration across various teams.
- The Team met with the Transportation Services Department to discuss a plan for future Service Center sites utilizing microgrid technology to support electrifying the fleet.

- Vendor implementation of DERMS interfaces (i.e., support for IEEE 2030.5/CSIP) was lacking maturity and required strong guidance from SCE.

Customer Benefits
- Evaluate the ability to fully electrify an SCE service center with large, high power and high energy fleet vehicles, DERs, and energy storage, electric space and water heating, all coordinated by a central control system to manage customer energy costs, minimize greenhouse gases, and maximize renewable energy, while responding to external grid controls to maintain stability.
- Efficient Electrification: The project will exhibit techniques for managing transportation electrification charges to optimize operations and control costs, thereby enabling large-scale fleet electrification. It will also illustrate the methods for servicing large-scale, high-power, high-energy electric fleets, along with coordinated communication and control with grid management systems.
- Cost Management and Integration: The project will demonstrate changes in costs through building electrification management (via BMS) and how this can be integrated with other Distributed Energy Resources (DER) systems.

15. Control and Protection for Microgrids and Virtual Power Plants

Investment Plan Period	Assignment to Value Chain
3rd Triennial Plan (2018 – 2020)	Distribution

Objective & Scope:

Project objectives include:
- Provide a standard method to assess a microgrid controller's performance in maintaining system stability by regulating power flows, managing voltage levels, and reducing frequency deviations within the microgrid. These factors are crucial for preventing disruptions or instabilities.
- Evaluate the controller's ability to isolate the microgrid from the upstream network, maintain critical loads, and facilitate reconnection to the grid. This capability is very important for ensuring the microgrid's operational independence and resilience.
- Analyze the reliability and dependability of the communication protocols and connections as well as ensure data integrity, both of which are vital to the efficient operation of the microgrid and prevention of potential disruptions.

The decision to focus on the University of California, Irvine's (UCI's) highly complex microgrid in this project was made with a goal of tackling real-world power system applications. However, due to the inherent complexities of the model and the need to adapt to the control and protection challenges posed by inverter-based resources (IBRs), the project team needed to make some reductions in the model to accommodate the computational limitations of the Real-

Time Digital Simulator (RTDS) software. Despite these changes, the model remained a robust representation of a microgrid power system, and the simulation verified the impacts of load disturbances, operational control strategies, smooth transitions, and auto synchronization on the microgrid's dynamic response.

From a control perspective, the project included the design of several layers of control to provide resilient and reliable microgrid operation. The primary layer of control regulated the voltage and frequency within the microgrid. A secondary control layer managed the overall microgrid operation, which included load shedding, islanding detection, fault detection, and isolation.

In addition, the project emphasized the strategic integration of Hardware-in-the-Loop (HIL) testing within the controlled confines of the lab environment to examine and assess the real equipment deployed in the field and earmarked for future microgrids.

This evaluation encompassed stress testing, performance testing, and resilience testing under a variety of use case scenarios, with a goal of confirming the system's efficiency and dependability, as well as detecting any weak points.

SCE completed this project 2024. SCE is still preparing the final project report, but when finished, SCE will submit it with the next annual report and will post it on PICG's public EPIC website.

Schedule:
Q3 2019 – Q2 2024

History of the project
SCE is continuing on the ambitious journey detailed in "Pathway 2045," a data-based analysis of the steps California must take to clean the electric grid and reach carbon neutrality in just two decades.

Pathway 2045 concludes that achieving decarbonization requires powering 100% of retail sales with carbon-free electricity, electrifying transportation and buildings, and using low-carbon fuels for technologies that are not viable for electrification.

Electrification will further increase customers' reliance on the grid, underscoring the need to build in additional resilience to withstand the more frequent and severe weather conditions due to climate change impacts.

Microgrids provide a promising solution to mitigate these challenges by offering the potential to alleviate some of the load when the grid is overloaded, or, during an outage, by deploying their Distributed Energy Resources (DER) assets, including clean energy sources such as solar power. This strategy can enhance system resiliency and stability, enabling SCE to continue providing reliable service while moving toward a more sustainable and carbon-neutral future.

As SCE has not yet integrated utility-operated microgrids into its grid, it is crucial to first thoroughly understand the Microgrid Control System (MCS). This includes comprehending its full capabilities and identifying potential operational challenges. Doing so can ensure a seamless

integration process, minimizing disruptions and maximizing the benefits of this technology. It is also vital to establish robust contingency plans and mitigation strategies to promptly and effectively address any unexpected complications.

To address the task of assimilating utility-operated microgrids into its power system, SCE undertook this project, using a dedicated microgrid testbed in a controlled lab environment. This provided the opportunity for testing and evaluation to determine next steps needed to bring a microgrid to field deployment.

2024 Status Update:

Accomplishment & Success Stories

- As noted in the 2023 Annual Report, the Fenwick Microgrid Lab test bed was fully functional with the following interfaces:
  - RTDS-based HIL testbed development process completed
  - Microgrid Control System (MCS)
  - RSCAD model
  - GTNET Interface including GOOSE and DNP3
  - GTAO and GTFPI
  - (2) SEL651RA Relays and SEL735B Power Meter
- Vendor SEL, along with SCE tech leads, certified that the Fenwick Microgrid Lab test bed (Microgrid Control System) met the contractual requirements, successfully passed final commissioning and site acceptance testing and successfully demonstrated all Use Cases.
- A laboratory-based Microgrid (MG) testbed was successfully installed and configured. The MCS was successfully interfaced with a Real Time Digital Simulator (RTDS) simulating the MG system (UC Irvine campus MG).
- Via simulation, the MCS interfaced with the SCE power grid, the MG critical facilities and several Distributed Energy Resources (DER's) such as Battery Energy Storage Systems (BESS), Solar Photovoltaic (PV) systems, Diesel Engines and Steam Turbine Generators.
- The MCS was able to automatically disconnect from the SCE power grid in the event of a scheduled outage and place the MG in island mode prior to the outage ensuring critical facilities remained energized via the DER's.
- The MCS was able to automatically disconnect from the SCE power grid in the event of an unplanned outage and place the MG in island mode after the outage occurred and prior to critical facilities being re-energized.
- The MCS effectively optimized the dispatch of generation assets within the MG to minimize the power mismatch between generation and consumption, ensuring a safe reconnection to the SCE grid.
- The learnings from this project will facilitate the design and performance evaluation of all future MG projects. Two EPIC 3 projects currently in progress, Smart City Demonstration and Service and Distribution Centers of the Future, will directly benefit from these learnings and will be utilizing the Fenwick Lab test bed.

- This testbed will act as a springboard for SCE to engage in and support future MG partnerships with external entities. All future MCS projects will be able to be tested under diverse conditions such as black start, islanded mode, and grid reconnection. This testbed will enable SCE to conduct a range of tests, yielding vital data that will enhance our comprehension of microgrids. This project is a steppingstone towards the development of sophisticated and dependable microgrid technologies for future applications.
- In terms of strategic alignment with EPIC goals and SCE customer benefits, the project's outcomes contribute to the development of more resilient and reliable microgrids. By conducting studies before field deployment, SCE can preempt potential issues, leading to the fine-tuning of control schemes, settings, and other parameters. This proactive approach aligns with EPIC's goal of advancing innovative clean energy solutions.

Challenges or Setbacks
- The project ended in Q2 2024 with no setbacks.

Key Findings and Lessons Learned
- Knowledge was gained in the network configuration of a microgrid system that can be used for all future microgrid projects (Pomona Microgrid Test Pad).
- Adding complication (additional elements: DER's, tie breakers) to the microgrid model makes it more difficult to perform tests, protection studies, troubleshooting and obtain results.
- During transition modes, the microgrid controller's role in sending and receiving commands to/from the grid forming asset is critical for maintaining the microgrid stability.
- The successful operation of the microgrid depends not only on the implementation of reliable and resilient control schemes but also on the establishment of a fast and reliable communication network.
- Delays in sending/receiving commands needs to be optimized via the microgrid controller code.
- Having two Battery Energy Storage Systems (BESS) in one clustered microgrid would sometimes cause stability issues, which was mitigated via optimizing inverter controller parameters.
- During a black start procedure, it is advisable to avoid connecting the generation units, especially the IBR units, simultaneously. This is because such a connection can cause significant disturbances, which may trigger frequency and voltage protection elements. To mitigate this issue, it is recommended to create time intervals for connecting generation units in the grid restoration scheme.
- Conducting studies before field deployment can preempt potential issues, allowing for the fine-tuning of control schemes, settings, and other parameters.
- In a microgrid islanded scenario, once a ground fault occurred, ground fault availability on the 12 kV system is dependent on the transformers (winding and size) from the BESS breakers. This is an important consideration for system design and operation.

- The SEL-751 relaying connected to the wye-to-ground/wye-to-ground PT can help detect the ground fault on the 12 kV system and act as backup protection for the DER. This finding underscores the need for comprehensive protection schemes.
- The study has shown that fuses added on the 12 kV side of all load transformers cannot be coordinated with corresponding relays due to the use of a generic fuse size 40E. This highlights the need for careful selection and sizing of protective devices.

Customer Benefits
- In terms of strategic alignment with EPIC goals and SCE customer benefits, the project's outcomes contribute to the development of more resilient and reliable microgrids. By conducting studies before field deployment, SCE can preempt potential issues, leading to the fine-tuning of control schemes, settings, and other parameters. This proactive approach aligns with EPIC's goal of advancing innovative clean energy solutions.
- For SCE customers, this translates into more reliable microgrid operations, minimizing disruptions and ensuring a stable power supply. The project's findings will guide future implementations, contributing to the development of robust and efficient microgrids.

Industry Advancement
- This project has made significant steps in microgrid controller system performance evaluation, contributing to the broader goals of enhancing grid resilience and reliability, and delivering tangible benefits to SCE customers.
- As the world of microgrid power systems continues to evolve, this testbed will enable us to continually enhance our distribution power system, making it more robust and reliable. It will also allow us to stay at the forefront of technological advancements, ensuring that our microgrid solutions are always up-to-date and effective.
- Moreover, by facilitating continuous learning and improvement, the test bed will play a crucial role in driving our organization's growth and success in the microgrid sector. It will not only help us deliver superior value to our customers but also contribute to the broader goal of promoting sustainable and resilient energy systems.

SCE is still preparing the final project report, but when finished, SCE will submit it with the next annual report and will make it available on PICG's public EPIC website.

16. Distributed Energy Resources (DER) Dynamics Integration Demonstration

Investment Plan Period	Assignment to Value Chain
3rd Triennial Plan (2018 – 2020)	Distribution
Objective & Scope	
This project aims to evaluate the two key technical challenges related to high DER penetration—protection system impacts and adverse interactions between multiple types of DERs.	

The project will be comprised of both hardware and software components: solar PV inverters, a lab testbed, and computer models of inverters, synchronous and induction generators, protective relay and one SCE sample feeder.

Test smart inverter functional capabilities on SCE distribution feeder with high DER penetration levels, it will be able to establish DER Operating Standards and leverage Smart Inverters for System-wide reliability.

Enhance interoperable controls capability at SCE to provide flexibility to the operation of the grid.

Schedule
Q4 2019 – Q4 2023

Status Update
The final project report is complete, was submitted with the 2023 Annual Report, and is available on PICG's public EPIC website.

17. Power System Voltage and VAR Control Under High Renewables Penetration

Investment Plan Period	Assignment to Value Chain
3rd Triennial Plan (2018 – 2020)	Grid Operation/Market Design

Objective & Scope
This project will demonstrate in a lab setting the effect of a voltage and VAR management and control algorithm that optimizes the operation of the power grid, for both the transmission and distribution systems, by regulating voltage and controlling VAR resources optimally while maintaining the secure operation of the power grid.

Status Update
During project planning, it was noted that additional research would be required for completion, which is not currently available, nor allowable for the Utilities to conduct under current EPIC requirements. SCE cancelled this EPIC project in 2020 with the intent of looking into alternative funding sources outside of EPIC.

18. Beyond Lithium-ion Energy Storage Demonstration

Investment Plan Period	Assignment to Value Chain
3rd Triennial Plan (2018 – 2020)	Distribution

Objective & Scope
The Beyond Lithium-ion Energy Storage Demonstration project will demonstrate the next wave of next-generation, precommercial, "beyond lithium-ion" energy storage technologies that have a high probability of commercial viability but require real world field experience to reduce technology and adoption barriers on the path to commercialization. This project will focus on advanced energy storage technologies that are non-lithium ion based (e.g., advanced electrochemical batteries, flow batteries, thermal storage, etc.). This project will demonstrate non-lithium-ion storage systems for a variety of traditional use cases (e.g., the CPUC's energy storage use cases outlined in D.13-10-040), and emerging use cases (e.g., regional/community

resiliency, etc.). Lastly, this project will demonstrate a complete energy storage system, including the storage technology, power conditioning systems, product/systems integration, and grid interconnection. The objectives of this project are to identify technologies most likely to achieve commercial viability within the next 3-5 years and opportunities to accelerate the commercialization process.

The adoption and integration of lithium-ion based energy storage systems has increased significantly in recent years, to the extent that it is widely considered a mature technology. Furthermore, advancements over the past decade in lithium-ion based energy storage systems have been facilitated by investment from federal and state government funding programs. SCE has been a leader in this regard, based on the company's successful energy storage demonstration completed under the federal government's American Reinvestment and Recovery Act (ARRA) via the Tehachapi Storage Project (TSP), the Irvine Smart Grid Demonstration (ISGD), and the energy storage systems deployed as a part of the Energy Storage Integration Project (ESIP).

To achieve California's ambitious long-term energy policy goals, and SCE's own Clean Power and Electrification Pathway 2045, the marketplace will require a diversity of cost-competitive energy storage products. This project will help to advance the industry's knowledge of lithium-ion alternatives to ensure new storage products can "cross the chasm" and compete with traditional storage technologies in the near-future.

Schedule
Q3 2020 – Q3 2025

Project History
In previous years, the project team experienced difficulty procuring a battery for testing. SCE engaged battery vendors; however, they were not able to produce a battery for testing within the project's timeline. In 2024 the Team contracted Quanta to assist in the procurement and testing of a battery. Through those joint efforts, the Team was able to purchase a nickel hydrogen battery from EnerVenue. The benefits of the EnerVenue battery are the 30-year lifespan, no need for fire suppression or HVAC, and low risk of thermal runaway.

Status Update
Accomplishment & Success Stories
• The Team procured a pre-commercial non-lithium-ion battery for testing from EnerVenue.
• The battery passed FAT testing at Quanta's facilities before being delivered by Crane and installed at the Pomona TSD labs.
• The Team has met with internal partners to discuss how the projects findings may provide insight to alternative options for long term battery storage.
• Procurement of the EnerVenue battery allowed the project team to acquire a battery ahead of previously forecasted timelines moving the projected project finish from Q1 2026 to Q3 2025.

Challenges or Setbacks

- The project faced substantial issues with procuring a battery that met the project's needs (pre-commercial non-lithium ion)
- The Team mitigated the issue by partnering with Quanta to procure the battery storage system.

Key Findings and Lessons Learned
- Most non-lithium-ion energy storage technologies are not at the same technical maturity as current lithium-ion energy storage options.
- Identified necessary processes and procedures for complying with local and federal requirements (permitting, hazardous materials business plan, etc.) for installing and operating non-lithium-ion battery system.

Customer Benefits
- Project findings will provide key insight as SCE looks to procure more energy storage systems.
- SCE feedback from testing results will help improve the final commercialized product that EnerVenue will be releasing.
- Helping to commercialize energy storage technologies that are more economically viable at the scale at which they need to be deployed.

19. Wildfire Prevention & Resiliency Technology Demonstration

Investment Plan Period	Assignment to Value Chain
3rd Triennial Plan (2018 – 2020)	Grid Operation/Market Design

Objective & Scope

This project will demonstrate the latest technology advancements in hardware-based solutions (e.g., field devices, sensors, protection devices, etc.) and software-based solutions (e.g., data analytics, climate, and fuel regrowth models, etc.) in support of climate adaptation and wildfire prevention, detection, and mitigation at all voltage levels. While SCE has outlined a comprehensive strategy and specific programs to address the year-round wildfire threat via the 2018 Grid Safety & Resiliency Program (GS&RP) application and 2019 Wildfire Mitigation Plan (WMP), those initiatives are focused on implementing commercial-ready technologies and strategies that are considered "shovel ready". This project intends to focus on new or emerging wildfire prevention and resiliency-focused technologies that have a high probability of commercial viability but require a more in-depth assessment and demonstration within the utility's operating environments in order to reduce technology and adoption barriers on the path to commercialization.

In the case of hardware-based technologies, SCE intends to demonstrate the next generation of distribution-level and transmission-level sensing, measurement, protection, and control technologies that are capable of detecting the presence of wildfires or operational abnormalities that may trigger wildfire ignitions (e.g., broken conductors) with greater speed and accuracy then what is currently available today in the marketplace.

In terms of software-based technologies, SCE intends to demonstrate the latest advancements in data analytics, climate, weather, and fuel growth modeling, etc., to enhance and expand the situational awareness and operational practice capabilities that are being implemented today. In addition, software-based technologies that can leverage the new hardware-based tools and technologies and provide improved resiliency, ignition prevention, fuels management, decision-support, automated high-speed control actions, etc. are also contemplated for this project.

Schedule
Q4 2021 – Q1 2026

Project History
To address future needs related to wildfires, reliability, resiliency, and situational awareness, this Proof-of-Concept project was developed to improve methods for sensing and monitoring grid conditions, collecting aerial data, and assessing equipment in the distribution grid.

Specifically, the aim of this project is to speed up damage detection, identify critical assets, determine the assets' damage level in real-time or near real-time, and understand grid event signatures that could lead to safety and reliability issues, potentially causing wildfires. The project can benefit from full access to distribution telemetry data and the ability to perform data analysis with its existing algorithms to address these challenges.

The project was initiated in Q4 2021 and is currently progressing through the execution phase. Distribution waveform analytics, the project's software-based technologies, is an area of interest for electric utilities. This portion of the project uses the high-resolution waveform data obtained from existing Digital Fault Recorders (DFR) and integrates them with other existing grid data sources like AMI and SCADA in a comprehensive grid situational awareness application to help detect and identify the more subtle types of faults that protection equipment is susceptible to not detecting. Arcing and high-impedance faults, which pose a high risk to wildfires, fall into this category. Similar technologies demonstrated through the WMP offer black box solutions that come with a steep deployment cost and ongoing service fees to operate. These solutions were standalone systems that lack flexibility in integration with other critical data sources needed for full grid situational awareness.

As mentioned in recent progress updates, the project team has successfully demonstrated the waveform analytics web application to the stakeholders, marking a major milestone. In the final phase, the web application will be able to group and categorize electrical signal patterns, demonstrate the use of distribution waveform analytics in a more real-time framework, and make the web application more useful for users. The final software-based technologies proof-of-concept demonstration is planned for Q2, 2025.

Status Update
<u>Accomplishment & Success Stories</u>
- In 2024, the Team demonstrated an anomaly detection algorithm for continuous waveform data. This algorithm, provided by a data science vendor, used High Pass Filter z-score

statistics and Fast Fourier Transforms to identify anomalies and compare them to a 'normal' baseline period.

- While the results were acceptable, the process was complex and required a lot of computational power.
- The Team then decided to try an internally developed algorithm from SCE experts, focusing on applying this method to big data using Spark due to the large volume of continuous waveform data.
  - They successfully built a Spark job that efficiently processed around 60 TB of data.
  - This new algorithm not only detected anomalies but also provided useful features for event clustering experiments.
  - In parallel to this, the end-user web application was built that focused on presenting relevant data about the waveform events combined with SCADA and AMI events and GIS map for event location.
  - The application was completed and demonstrated to stakeholders in Q4 2024.
- The "sandbox" data platform demonstrated by this project has a limitation: it doesn't get live data from other grid sources like AMI and SCADA.
  - However, the Team successfully showed key techniques for storing and processing waveform data, detecting anomalies, and extracting useful features for machine learning.
  - The Team also demonstrated how to use this data in an application for grid operators to improve situational awareness.
  - The Team is now testing ways to move from offline to live data processing, though it does face challenges due to outdated software versions.
- The Team has discussed with SCE's Digital Fault Recorders (DFR) vendor and other DFR vendors about improving DFRs to deploy advanced waveform detection algorithms at the edge. The Team also talked with software vendors offering off-the-shelf data platforms for waveform data analytics.
  - The Team met with another IOU to share findings and learn how each utility is tackling this challenge.

Challenges or Setbacks
- The project faced substantial issues with hardware and software not meeting project requirements.
- Hardware issues included:
  - Hardware Limitations: Vendor solutions failed to meet design needs.
  - Vendor Challenges: Vendors were reluctant to install custom software.
  - NDAA Compliance: Changing National Defense Authorization Act (NDAA) laws increased compliance risks.
  - Vendors struggled to sign EPIC T&Cs due to the new Intellectual Property (IP) development required for software and hardware customization deliverables.

- Due to the challenges with the hardware vendors, the Team has decided to emphasize the software solutions and de-emphasize the hardware solutions, and as a result, the project is expected to finish earlier than originally anticipated.
- Another challenge is that the demonstrated application is a static, not live, proof-of-concept, which means the Team cannot test it in real grid operations. While the Team showed correlations between detected waveforms and historic failures, the Team could not get real-time feedback from grid operators on its effectiveness in preventing equipment failures. The Team believes a future pilot project may allow testing in a real grid setting.
  - The Team is providing feedback to the project's platform software vendor to propose a next-generation architecture for working with real-time data.
- This project platform is built entirely on premises. Most software vendors offering similar data platforms are cloud-based, which can be restrictive for utilities that prefer on-premises solutions to protect sensitive data.

Key Findings and Lessons Learned
- Power system events can be complex and challenging, as techniques like Fast Fourier Transform (FFT) work well in theory but fail in real-world conditions. The data science vendor initially struggled with this complexity.
  - Through collaboration with the data science team and power systems experts, SCE learned the importance of having a strong background in both power systems and signal processing. The data science vendor initially struggled with this complexity.
- The Team focused on improving Digital Fault Recorders (DFR) by demonstrating a tool to monitor issues in real time, such as stations going offline and clock sync problems, which can make the data useless if not fixed.
- The Team also recommended standardizing channel names to reduce errors in data processing and adjusting event trigger settings to capture subtle events. If this project is deployed in production, deploying edge agents would become a standard part of the DFR setup process.

Customer Benefits
- The project helps to quickly detect issues that could cause wildfires and thus can mitigate potential disasters, protecting customers' lives, homes, and communities.
- Leveraging existing equipment instead of building new equipment helps improve affordability for customers over time.
- Faster detection of operational issues means fewer outages and disruptions, ensuring customers enjoy consistent and reliable electricity.
- Enhancing reliability and safety minimizes unexpected repairs and large-scale disruptions, which could help stabilize or lower customer rates in the long run.

Industry Advancement

- The learnings from this project have been widely shared with the industry. The Team published two conference papers and presented them at the IEEE PES 2024 T&D conference. The project was also showcased at the 2024 IEEE Joint Technical Committee Meeting and the 2024 IEEE General Meeting. Additionally, it was nominated for the "Data Impact Award" by the software vendor Cloudera and presented at Cloudera's Evolve 2024 conference alongside other companies working on advanced data solutions.
- The Team is part of the IEEE Taskforce "Big Data Analytics for Synchro-waveforms." The Team contributed to the Taskforce's 2024 white paper, which provides guidelines for managing and processing waveform data at the utility-scale. This has led to collaborations with multiple National Labs to develop advanced fault detection algorithms using waveform data. This project serves as the platform to transition these algorithms from research to production. Currently, SCE is working with Lawrence Livermore National Lab and Oak Ridge National Lab, sharing learnings from the project.

(4) 2020 – 2025 Investment Plan Projects

1. Flexible Alternating Current System (FACS)

Investment Plan Period	Strategic Objective & *Research Topics*
1st Quinquennial Plan (2021 – 2025)	T&D Situational Capabilities *High-Capacity Throughput and Protection, Seamless Grid Flexibility*

Objective & Scope

This project aims to demonstrate how power quality conditioners (PQCs) can cost-effectively integrate renewable resources and meet additional load requirements compared to traditional grid reinforcement infrastructure upgrades, which in some cases can be more expensive. By monitoring and regulating voltage, reactive power, and power flow, PQCs enhance grid utilization and resilience without the need for costly grid reinforcement.

This project will investigate the performance and system benefits of power quality conditioner technologies to improve system utilization and overall reliability.

Power quality conditioners, including Distribution STATCOMs, hybrid transformers, and energy storage systems, will be explored to demonstrate how to mitigate voltage issues on distribution circuits caused by high DER penetration. By regulating voltage and correcting power factor, these technologies address voltage constraints faced by distribution system operators. Without such solutions, additional grid interconnections may be hindered, necessitating costly grid reinforcements or infrastructure upgrades on weaker circuits.

Schedule

Q2 2024 – Q3 2029

Project History

SCE's current distribution grid system faces several challenges due to the increasing penetration of distributed energy resources (DERs) and industrial loads. These challenges include reverse

power flow, voltage fluctuations, and power quality issues, which can affect grid stability and reliability. Traditional solutions such as reconductoring, dedicated feeders, and switched capacitor banks are employed to manage these issues, but they are often costly, slow to implement, and inefficient for dynamic power quality management.

The existing system relies on conventional methods for voltage control and reactive power compensation. These methods include the use of static VAR compensators (SVCs) and passive or active harmonic filters. While these solutions provide some level of voltage support and harmonic mitigation, they lack the flexibility and dynamic response required to address the rapid changes in power quality and voltage stability associated with high DER penetration.

Energy storage systems, demand response programs, and smart inverters are also part of the current system's approach to managing voltage and reactive power. However, these technologies have limitations in capacity, availability, and coordination, making them less effective for comprehensive grid stability. Energy storage systems can offer temporary voltage support, but their long-term sustainability is a concern. Demand response programs depend on customer participation, which can be unreliable, and smart inverters require extensive coordination to achieve desired outcomes.

The proposed changes to the current distribution grid system involve the integration of PQCs to dynamically regulate voltage and reactive power, addressing the limitations of traditional methods. These changes are driven by the need for a more flexible, scalable, and cost-effective solution to manage the challenges posed by high DER penetration and industrial loads.

By deploying PQCs, the system will benefit from enhanced voltage stability, improved PF, and ancillary services such as harmonic filtering and flicker mitigation. This approach not only supports the integration of more renewable energy sources and electric vehicle infrastructure but also aligns with California's decarbonization goals, providing significant community benefits in disadvantaged and vulnerable areas.

The rationale for these changes is to ensure a reliable, resilient, and sustainable distribution grid that can adapt to the evolving energy landscape.

Issues identified in circuits, including voltage fluctuation, harmonics and capacitor resonance, led to the launch of this project. Capacitors are used to help with voltage regulation and provide reactive power for the system, but they can cause resonance. SCE is trying to find ways to mitigate these issues. Projects have been undertaken to install voltage regulators to replace the capacitor banks and avoid capacitor resonance. However, while voltage regulators can mitigate voltage issues, they can't provide reactive power for power factor correction or free up circuit capacity. STATCOMs provides reactive power, mitigates voltage issues, and filters harmonics.

Potential Limits with this Project:
- The project may face challenges in field deployment, such as regulatory or contractual barriers, permitting, interconnection, or environmental issues.

- Sending and receiving signals from the control center through SCADA may increase implementation time.
- SCE is prioritizing D-STATCOM deployment locations that benefit disadvantaged communities, which may limit the search space for the optimum location.

Future Questions:
- How can PQCs be further optimized to handle even higher levels of DER penetration?
- What are the long-term impacts of PQC deployment on grid resilience and reliability?

Status Update

Accomplishment & Success Stories
- Charter Document Development and Approval: The project charter document has been successfully developed and approved. This document outlines the project's objectives, scope, and key deliverables, providing a clear roadmap for the project's execution.
- Preliminary Study for Optimal STATCOM Placement: A preliminary study has been conducted to identify the search space for the optimal placement of the STATCOM. This study involved analyzing data from various distribution circuits to determine the level of STATCOM necessity for mitigating existing challenges. The chosen locations will maximize the benefits of voltage regulation and power quality improvement.
- The Team presented the project to SCE's Community Advisory Board to solicit feedback on how the project could help various communities within the SCE territory.

Key Findings and Lessons Learned
- The Team analyzed a year's worth of voltage and harmonics data and built a tool to prioritize locations based on their vulnerability to power quality issues such as voltage regulation, individual harmonics, and THD. This tool will help the Team identify the final location of the STATCOM in the distribution system.

Customer Benefits
- Improved reliability and safety by enabling the integration and utilization of more DERs and electrified loads.
- Avoided emissions through enhanced grid utilization and support for California's decarbonization goals.
- Increased electrification, supporting the integration of more electric vehicle charging infrastructure and improving local air quality.
- The Team will select a substation that serves disadvantaged communities (DACs) to conduct the project and place the STATCOM. By prioritizing these areas, SCE can enhance the resilience and reliability of the distribution grid for these communities, ensuring they benefit from improved voltage regulation and power quality. This approach aligns with our commitment to providing equitable and sustainable energy solutions for all customers.

Anticipated RFPs

- SCE will be launching an RFP to secure services for engineering, procurement, testing, and field deployment of one D-STATCOM. By engaging qualified vendors, SCE hopes to ensure that the necessary expertise and resources are in place to successfully implement and demonstrate the benefits of PQCs. This will help us achieve our goals of improved voltage regulation, power quality, and overall system performance.

2. ML-Augmented Digital Simulation (MAD-S)

Investment Plan Period 1st Quinquennial Plan (2021 – 2025)	Strategic Objective & *Research Topics* Digital Transformation *Data Driven Operations, End-to-End Advanced Simulations and Analytics*

Objective & Scope

The future electric grid will face greater load and generation variability than ever before. The impact on the grid and our customers must be constantly tracked and seamlessly integrated into processes such as planning to optimize decision making. This is a big data + engineering effort that requires innovation and collaboration aimed at improving power flow engine results by augmenting results with a digital twin platform to analyze grid data and integrate predictive analytics to improve LF engine assumptions.

This project aims to demonstrate the capabilities of an open, modular, and scalable infrastructure that supports a variety of machine learning applications. By leveraging diverse data types, including contextual information, the platform aims to provide a robust backbone for these ML-based solutions, ensuring they can be effectively developed, integrated, and deployed to meet the evolving needs of the energy sector.

Schedule

Q2 2024 – Q3 2027

Project History

The project was launched to address the inadequate infrastructure and processes required for scaling data and model-dependent solutions. Current technologies were found lacking in supporting AI (Artificial Intelligence) applications that necessitate optimal, data-driven decision-making.

Previously, SCE managed several EPIC 3 projects such as GT-19-0004 Wildfire Prevention & Resiliency Technology Demonstration (WP&RT), GT-18-0002 Advanced Technology for Field Safety (ATFS), and various machine learning (ML) applications that relied heavily on data. However, these applications required the creation of data pipelines from scratch. This presented an opportunity to develop a platform for data integration, enabling these applications to function cohesively. To address these issues, SCE initiated several capital projects, including SPEED and GCM. Despite these efforts, the previous initiatives had limitations in supporting the applications effectively.

The project team is concluding the Design Thinking Phase and is initiating the planning phase which will develop project requirements, schedules, budget allocations, and overall project plan.

Status Update

Accomplishment & Success Stories

- In Q4, 2024, the Team aligned with other Digital Twin initiatives within SCE to avoid duplication and enhance visibility. The Team conducted multiple calls with various SCE organizations to present design thinking outcomes and finalize the use case and scope.
- In Q1, 2025, the project team is preparing to issue a Request for Information (RFI) to obtain market insights on vendor offering off-the-shelf solutions. The information gathered will clarify requirements, support informed decision making, and ensure the project starts with clear, well-defined objectives, and strategies.
- The Team presented the project to SCE's Community Advisory Board to solicit feedback on how the project could help various communities within the SCE territory.

Key Findings and Lessons Learned

- The project team plans to issue an RFI to gather vendor insights which will help clarify requirements and ensure the project is executed with clear objectives and strategies.

Customer Benefits

- The project ensures that the data used for different machine learning based applications is leading to more accurate decision making and improved grid reliability.
- By using smart technology to combine different ML applications, the platform will make better and more efficient decisions. This helps predict energy needs accurately, which in turn lowers operational costs, improving customer affordability.

Anticipated RFPs

- In Q1 2025, the project team plans to issue an RFI to gather vendor insights and will initiate and RFP later.

Industry Advancement

- This project advances the technical roadmap by enhancing predictive analytics, machine learning, and data integrity, leading to more accurate and context-aware planning models for grid modernization.

3. Quantum Networking

Investment Plan Period	Strategic Objective & *Research Topics*
1st Quinquennial Plan (2021 – 2025)	T&D Foundational Technologies *Ultra Low-Latency Communications*
Objective & Scope	
This project will fortify SCE grid against modern threats using advanced quantum technologies. Quantum-enhanced security measures will protect the grid from cyber threats, including future attacks where data is stored now to be decrypted later. Additionally, high precision	

synchronization systems, developed for quantum networks, will safeguard the grid from GPS spoofing attacks and provide a reliable alternative during GPS outages, whether they are malicious or incidental. These innovations aim to ensure the security and reliability of the grid.

Schedule
Q2 2024 – Q4 2028

Project History
This project was originally submitted as part of a national lab request to the DOE. At that time, the DOE response was that, as described, the project was a demonstration of the technology, not research, and the funding opportunity for the national lab was for research. Due to this description as a technology demonstration by the DOE and SCE's continuing interest in the project, SCE explored whether the project would fit into SCE's EPIC 4 plans. This project will be one of the first instances of the application of the Quantum Networking technology outside of the national lab environments.

This project will implement the Quantum Network technology over SCE-owned, presently dark, fiber to validate the commercial application of the technology on "production" grade infrastructure. SCE will evaluate the cybersecurity implications of the technology in the post quantum computer era. Upon completion of the project an evaluation of the technology will be performed to determine the next steps in the application of the technology.

Status Update
Accomplishment & Success Stories
- The project team completed the project initiation and is well into the project planning phase. The concept of operations is in the final review and the project plan has been started.
- The Team has evaluated the initial activity and documented several use cases for examination.
- The Team also met with internal partners to discuss or plan the project phasing.
- The Team continues to develop and finalize the project plan in preparation to execution.
- The Team will present the project at UTC conference in June 2025.
- The Team presented the project to SCE's Community Advisory Board and has the Board's support for the proposed training development plan.

Challenges or Setbacks
- The project faced a substantial issue with identifying community benefits due to the base infrastructure nature of the project.
    - The Team mitigated the issue/risk by working with CalTech and Bohr Quantum, and SCE identified an opportunity to create workforce training in the technology that would support the communities without requiring a degree in quantum physics.
    - The Team plans to implement the training goals listed above to resolve the challenge.

Key Findings and Lessons Learned

- Through internal and external discussions with stakeholders, the Team learned of the potential of the project to provide valuable cybersecurity in the post quantum compute world.

Customer Benefits
- The primary customer benefit is the reduction of the vulnerability to cybersecurity attacks if the technology proves out and is implemented.
- The primary benefit is the hardening of SCE's telecommunication infrastructure to some cybersecurity attacks.
- If the technology is proven successful, SCE will evaluate whether and how to deploy it to the SCE Grid Communications infrastructure.

Industry Advancement
- The Team is scheduled to present at the UTC conference in June. Other opportunities will arise as the project progresses.

4. Swift Electrification of Transit (SET)

Investment Plan Period	Strategic Objective & *Research Topics*
1st Quinquennial Plan (2021 – 2025)	Energy Management Situational Capabilities *Energy Buffering, Islanding and Reconfigurability*

Objective & Scope
Currently, customers electrifying fleets at times can wait several years for service while the necessary grid upgrades are made. This results in dissatisfied customers waiting much longer for service, delays in fleet electrification, and regulatory penalties for customers (not meeting State & Federal requirements). Customers desire charging infrastructure solutions that reduce planning complexity/uncertainty, deployment time, footprint and cost while meeting their resiliency expectations. Potential outcomes of this project include industry advancement, customer benefits, and community engagement.

Schedule
Q2 2024 – Q4 2027

Project History
The project began as a result of customers having long wait times, often times years, to electrify fleets due to the need for grid upgrades. Through a design thinking process, SCE documented many of the concerns from both SCE's as well as the customers' perspectives, which helped inform the project on how to address concerns such as grid outages and long wait times.

The project aims to prove technologies that can reduce emissions (clean generators), provide resiliency (microgrid), and help expedite electrification through standardized systems. Some limitations within this project will come down to the reliability of technologies such as solid-state transformers, which will be evaluated in the lab for field readiness.

Status Update

Accomplishment & Success Stories

- The Team identified new sources of customer value, including energizing customers within months with a standardized modular bridging solution as well as resiliency for both the grid and customer with microgrid capabilities.
- The Team validated customer benefits of an expedited connection through verifying existing connection times.
- The Team evaluated potential clean generators, non-lithium-ion energy storage systems, controllers, and solid-state transformers.
- The Team met with internal partners to discuss standardization of bridging solutions as well as dynamic load constraint management systems.
- The Team continues to evaluate the interconnection of the supervisory control system to SCE DERMs.
- The Team presented the project to SCE's Community Advisory Board to solicit feedback on how the project could help various communities within the SCE territory.

Challenges or Setbacks

- The project faced a substantial issue with potential non-lithium-ion energy storage systems and solid-state transformers available in the market.
- The Team mitigated the issue/risk by narrowing vendors down to the most commercially viable.
- The Team plans to develop a backup plan to resolve the challenge if either of the technologies prove unreliable during the lab phase.

Key Findings and Lessons Learned

- Through internal and external discussions with our stakeholders, SCE learned that a standardized solution of generators plus energy storage systems would benefit both internal initiatives while also providing quicker interconnections to our customers. By utilizing a standardized approach, SCE will be able to choose off-the-shelf designs to rapidly interconnect customers who are waiting for a circuit upgrade.

Customer Benefits

- The project will result in a standardized modular Generation plus Energy Storage System block which could be deployed territory-wide to bridge the gap on customers waiting for circuit upgrades. This can range from 500kW – 10MW.
- This project will support DACs through utilizing the findings to help support electrification of public transportation systems as well as getting customers connected quicker while they await circuit upgrades to be complete.
- This project will test new, clean-energy generators as well as non-lithium-ion energy storage systems to help achieve the state's clean energy and climate goals.

Anticipated RFPs

- Non-Lithium-Ion Energy Storage System
- Clean Energy Generators (Linear, Propane/Natural Gas)

- Microgrid Control System

Industry Advancement
- While there haven't been any standards development yet, the project aims to standardize modular generation blocks utilizing generators and energy storage systems.
- The project has had an influence on the need for a bi-directional solid-state transformer. At this time there has only been a uni-directional SST developed.
- The project is helping test dynamic load constraint management systems as well as standardizing generation blocks to inform various SCE teams.

5. Stability Improvement with DERs (SIDER)

Investment Plan Period	Strategic Objective & *Research Topics*
1st Quinquennial Plan (2021 – 2025)	Energy Management Foundational Technologies *Customer Load Flexibility*

Objective & Scope

This project aims to demonstrate innovative technologies for the integration of aggregators and Distributed Energy Resources (DERs) to achieve grid flexibility through smart management and adaptability. The objective of SIDER is to demonstrate distribution load flexibility capabilities by integrating Distributed Energy Resources Management Systems (DERMS) to orchestrate customer-owned resources (such as EVs and other DERs).

This involves utilizing intelligence from SCE's grid management system, ADMS, and DERMS planning, forecasting, optimization, and analytics, along with using close to real-time communication with aggregated customer-owned resources or other SCE edge devices.

SIDER aims to onboard and register multiple EV Original Equipment Manufacturers' (OEMs') Aggregators to SCE's DERMS, enable the DERMS to establish reliable CSIP IEEE 2030.5 communication with aggregators, collect EV data from aggregators and EV OEM systems, dispatch a day ahead or close to real-time commands to EVs through aggregators (load forecast, charge schedule and price signals), incorporate updated EV schedule data from aggregators, and provide bi-directional EV charge commands to enable EVs to export energy to home or grid.

Project Schedule

Q2 2024 – 2028

Project History

The demand on the grid will increase significantly over the next few years due to the increase in EV's and their charging demand, especially during peak charging times. This can lead to grid instability, reliability, and safety issues in circuit sections of the grid where equipment and conductors have insufficient capacity to meet customer demands.

The Stability Improvement with DERs (SIDER) project will look to provide continuous monitoring and communicating with EVs and related charging stations to utilize a large amount of EVs from different EV manufacturers (OEMs) across the SCE's territory to understand EV owners' charging

behavior, analyze EV's charging data, provide & test a mechanism to dynamically update and apply the charging schedules to minimize the possibility of transformers and cables/conductors from overloading & overheating, provide load demand flexibility and support grid's voltage & frequency events. The project initially planned to also explore inertia substitution but decided to focus on the areas noted above. As a result, SIDER will defer work addressing the Inertia Substitution Research Topic.

The SIDER team has had ongoing discussions with other related SCE Vehicle to Grid (V2G) project teams, including EPIC projects like Vehicle-to-Grid Integration Using On-Board Inverter (V2G) and capital projects to leverage prior learnings and coordinate future plans. The Team is also working with SCE's Customer Service group to explore Energy Efficiency incentive programs that could support SIDER.

The Team is also exploring ways that SIDER could contribute to SCE's planned wildfire rebuild effort.

Status Update

Accomplishment & Success Stories
- This project was kicked off with a Design Thinking Phase which initiated project discussions on problem statement, issues, proposed solutions, objectives, and goals.
- SCE identified the SIDER project team as well as an internal SCE sponsor, potential additional funding sources and internal stakeholders.
- The Team completed research on stakeholder needs and pain points.
- The Team held discussions with outside vendors interested in collaborating with SCE on the project.
- The Team drafted Project Charter documents and presented to Stakeholders and Sponsors for final approval. The Charter document stating the project scope, objectives, and expected deliverables is currently being revised to incorporate feedback/comments.
- Discussions with key internal sponsors and third-party EV manufacturers are ongoing.
- The next steps include finalizing plans for a vendor RFP and lab testing.
- The Team presented the project to SCE's Community Advisory Board to solicit feedback on how the project could help various communities within the SCE territory.

Challenges or Setbacks
- Most customers prefer the flexibility to charge their vehicles whenever they need, rather than adhering to a fixed schedule by DERMS. The unpredictability of daily driving patterns makes it difficult for customers to commit to a fixed schedule for V2G.
  - To address this challenge, the Team focused on more specific DERMS functions from a site perspective, including dispatching the "schedule" commands, and export/import limits.
  - Other types of functionalities may be more difficult to manage, especially for EVs or from public charging stations, depending on EV OEM types.
- Not all EVs and charging infrastructure are currently compatible with V2G technology and there is a cost to install and implement V2G capabilities, which can limit participation of that type of DER.

- Integration challenges of SIDER with various types of DERs can be complex and may lead to compatibility issues.
- SIDER will depend heavily on digital communication and data exchange. Vulnerability to cyber-attacks will require cybersecurity reviews and approvals. SIDER will adhere to Cyber-Informed Engineering Principles.
- The technical complexity of implementing advanced features like real-time monitoring, machine learning, and predictive analytics can pose significant challenges.

Key Findings and Lessons Learned
- The Team is still performing detailed planning.

Customer Benefits
- Maintain community reliability and resilience with existing or planned community resources.
- Increase the potential use of DERs, including customer EVs, to provide grid flexibility services.
- Enable further electrification, including EV ownership and value, consistent with VGI principles.
- Partner with local community and educational institution to deploy DER intelligence and management systems.
- Foster EV V2G use case evaluations in local communities.
- Engage STEM programs with system data aggregation and analysis.

Anticipated RFPs
- The Team is finalizing plans for an OEM vendor RFP.

Industry Advancement
- Demonstrate advanced grid Load Flexibility technologies to support customer load flexibility.
- Demonstrate CSIP IEEE 2030.5 communication, dispatching schedule commands with third party aggregators to monitor, control and optimize DER resources.
- Demonstrate coordinated community/area support with DERs, V2G and load flexibility.

5. **Conclusion**

   a) **Key Results for the Year for SCE's EPIC Program**

      (1) **2012 – 2014 Investment Plan**

      For the period between January 1 and December 31, 2024, SCE expended a total of $(19,494)[60] toward project costs and $0 toward administrative costs for a grand total of $(19,494). SCE's cumulative expenses over the lifespan of its 2012 – 2014 EPIC 1 program amount to $38,642,227.

---

[60] SCE is reviewing these credits.

SCE initiated 16 projects, cancelled one project, and completed 15 projects. Three of these projects were completed during the calendar year 2015, four projects were completed in 2016, four projects were completed in 2017, two projects were completed in 2018, one project was completed in 2019, and one project was completed in 2020.

The list of 15 completed 2012 – 2014 Investment Plan projects is shown below:

1. Integrated Grid Project Phase 1

2. Regulatory Mandates: Submetering Enablement Demonstration

3. Distribution Planning Tool

4. Beyond the Meter: Customer Device Communications, Unification and Demonstration (Phase II)

5. Portable End-to-End Test System

6. Voltage and VAR Control of SCE Transmission System

7. State Estimation Using Phasor Measurement Technologies

8. Wide-Area Reliability Management & Control

9. Distributed Optimized Storage (DOS) Protection & Control Demonstration

10. Outage Management and Customer Voltage Data Analytics Demonstration

11. SA-3 Phase III Demonstration

12. Next-Generation Distribution Automation, Phase 1

13. Enhanced Infrastructure Technology Evaluation

14. Dynamic Line Rating Demonstration

15. Cyber-Intrusion Auto-Response and Policy Management System (CAPMS)

(2) 2015 – 2017 Investment Plan

For the period between January 1 and December 31, 2024, SCE expended a total of $967,743 toward project costs and $199,458 toward administrative costs for a grand total of $1,167,202. SCE's cumulative expenses over the lifespan of its 2015 – 2017 EPIC 2 program amount to $39,437,223. SCE committed $843,637 toward projects and encumbered $580,114 through executed purchase orders during this period. SCE has no uncommitted EPIC 2 funding for this period.

SCE initiated 13 projects from its approved portfolio and cancelled 3 projects for the reasons described in their respective project updates section. Of the remaining ten projects, one project was completed in 2017, three projects were completed in 2018, two projects were completed in 2019, one project was completed in 2020, one project was completed in 2021, and one project was completed in 2022. One project remains in execution for the 2015 – 2017 Investment Plan.

SCE's 2015 – 2017, EPIC 2 program has the following project remaining in execution:

1. System Intelligence and Situational Awareness Capabilities

The list of nine (9) completed 2015 – 2017 Investment Plan projects is shown below:

1. Integration of Big Data for Advanced Automated Customer Load Management
2. Advanced Grid Capabilities Using Smart Meter Data
3. Proactive Storm Impact Analysis Demonstration
4. Next-Generation Distribution Equipment & Automation – Phase 2
5. Regulatory Mandates: Submetering Enablement Demonstration – Phase 2
6. Versatile Plug-in Auxiliary Power System
7. Dynamic Power Conditioner

8. DC Fast Charging

9. Integrated Grid Project II

(3) **2018 – 2020 Investment Plan**

For the period between January 1 and December 31, 2024, SCE expended a total of $3,013,955 toward project costs and $362,550 toward administrative costs for a grand total of $3,376,505. SCE's cumulative expenses over the lifespan of its 2018 – 2020 EPIC 3 program amount to $28,511,963. SCE committed $9,431,542 toward projects and encumbered $5,557,907 through executed purchase orders during this period. SCE has no uncommitted EPIC 3 project funds for this period.

SCE initiated 19 projects from its approved portfolio. As of this report, SCE cancelled two projects, deferred two projects, and began executing 15 projects from its approved portfolio. Of these remaining 15 projects, one project was completed in 2021, one project was completed in 2022, one project was completed in 2023, and two projects were completed in 2024. Ten projects remain in execution for the 2018 – 2020 Investment Plan.

SCE's 2018 – 2020 EPIC 3 program has the following ten (10) projects remaining in execution:

1. Advanced Technology for Field Safety (ATFS)

2. Beyond Lithium-ion Energy Storage Demo

3. Distributed Plug-In Electric Vehicle Charging Resources

4. Next Generation Distribution Automation III

5. SA-3 Phase III Field Demonstrations

6. Service and Distribution Centers of the Future

7. Smart City Demonstration

8. Storage-Based Distribution DC Link

9. Vehicle-to-Grid Integration Using On-Board Inverter

10. Wildfire Prevention & Resiliency Technology Demonstration

The list of five (5) completed 2015 – 2017 Investment Plan projects is shown below:

1. Cybersecurity for Industrial Control Systems
2. Distributed Cyber Threat Analysis Collaboration
3. Advanced Comprehensive Hazards Tool
4. Control and Protection for Microgrids and Virtual Power Plants
5. Distributed Energy Resources (DER) Dynamics Integration Demonstration

(4) 2021 – 2025 Investment Plan

For the period between January 1 and December 31, 2024, SCE expended a total of $4,698 toward project costs and $6,098 toward administrative costs for a grand total of $10,796 SCE's cumulative expenses over the lifespan of its 2021 – 2025 EPIC 4 program amount to $10,796. SCE budgeted $39,000,000 toward projects and encumbered $0 through executed purchase orders during this period out of its total EPIC 4 project budget of $68,051,325 during 2024.

SCE began executing five (5) projects from its approved portfolio.

SCE's 2021 – 2025 EPIC 4 program is currently composed of the following five (5) projects remaining in execution:

1. Flexible Alternating Current System (FACS)
2. ML-Augmented Digital Simulation (MAD-S)
3. Quantum Networking
4. Swift Electrification of Transit (SET)
5. Stability Improvement with DERs (SIDER).

b) Next Steps for EPIC Investment Plan (stakeholder workshops etc.)

The progress made by SCE project teams across multiple initiatives is commendable, despite facing procurement delays and vendor challenges. All of the EPIC projects are expected to deliver substantial benefits to customers, enhancing the resilience and sophistication of utility infrastructure.

SCE's proactive engagement with regulatory bodies and stakeholders was crucial in advancing its EPIC 4 Investment Plan Application and successfully launching the first wave of EPIC 4 Projects in 2024. The company has also made significant progress in the EPIC successor program's rulemaking process. The focus has been on completing the 2015 – 2017 Investment Plan and advancing the projects from the 2018 – 2020 and 2021 – 2025 Investment Plans. The comprehensive approach taken by SCE ensures that the company continues to advance EPIC and SCE objectives.

Following the approval of the EPIC 4 Investment Plan, SCE and other Utilities convened to strategize on portfolio implementation. SCE hosted workshops to explore strategic initiatives, addressing opportunities, challenges, and community needs, with a focus on engaging disadvantaged communities. Public workshops and the annual Symposium served as platforms for SCE and EPIC Administrators to discuss key topics with stakeholders and the Commission, sharing achievements and insights from the EPIC programs. Looking ahead to 2025, SCE will continue this engagement, as well as working with its EPIC Community Advisory Board, to launch its next wave of EPIC 4 projects.

Following the success in advancing and completing existing projects and launching new projects that, as described above in the Project Status Reports, continue to provide benefits to ratepayers, SCE hopes it, together with the other IOUs, will be able to continue as EPIC Administrator for the upcoming EPIC 5 investment cycle. SCE actively participated in the regulator's public workshops to define EPIC 5's Strategic Goals and Strategic Objectives during 2024. If afforded the opportunity to continue as an Administrator for EPIC, SCE would continue its process of proactively engaging with regulatory bodies and the community, as well as with SCE's EPIC Community Advisory Panel, in defining Strategic Initiatives and projects in support of EPIC 5's Strategic Goals and Strategic Objectives.

SCE maintained collaboration with the Policy Innovation + Coordination (PICG) Coordinator on the EPIC project database and will continue its open dialogue with the stakeholders through public engagement in 2025.

c) <u>Issues That May Have Major Impact on Progress in Projects</u>

In 2025, SCE is committed to the effective completion of its final project under the EPIC 2 Investment Plan. Additionally, SCE will progress with the execution of the 10 remaining projects from the EPIC 3 Investment Plan and the 5 projects launched in from the EPIC 4 Investment Plans, and it will also launch more EPIC 4 projects.

In 2024, SCE faced numerous issues that had a major impact on project progress. Due to concerns about the legal interpretation of IP flowdowns under EPIC rules, SCE had difficulties working with vendors, to the point that SCE had to cancel a project because vendors would not agree to the terms. This issue affected other projects, including, from EPIC 3, the Advanced Comprehensive Hazards Tool and the Wildfire Prevention & Resiliency Technology Demonstration projects. Furthermore, SCE had extended negotiations with vendors in some projects that sometimes were not able to ultimately come to an agreement. Finally, addressing cybersecurity concerns across all projects has added to project development timetables.

Moving forward, SCE will persist in vigilantly overseeing potential project postponements, including those stemming from production and supply chain disruptions as well as disputes over EPIC's IP terms and conditions.

APPENDIX A

ADVANCED COMPREHENSIVE HAZARDS TOOL

FINAL PROJECT REPORT

Advanced Comprehensive Hazards Tool EPIC Phase III
Final Project Report
GT-18-0012

Developed by
SCE Asset Strategy and Planning

Southern California Edison
2131 Walnut Grove Avenue
Rosemead, CA 91770

Acknowledgments

Disclaimer

Table of Contents

List of Figures

List of Tables

Definitions

Adaptive capacity is the "combination of the strengths, attributes, and resources available to an individual, community, society, or organization that can be used to prepare for and undertake actions to reduce adverse impacts, moderate harm, or exploit beneficial opportunities" (Intergovernmental Panel on Climate Change (IPCC), 2012).

Exposure "is the presence of people, infrastructure, natural systems, and economic, cultural, and social resources in areas that are subject to harm" (IPCC, 2012).

Resilience is the "capacity of any entity – an individual, a community, an organization, or a natural system – to prepare for disruptions, to recover from shocks and stresses, and to adapt and grow from a disruptive experience" (Rodin, J. *The Resilience Dividend*, 2014). Adaptation actions contribute to increasing resilience, which is a desired outcome or state of being (California's Fourth Climate Change Assessment Statewide Summary Report).

Sensitivity is the level to which a species, natural system, or community, government, etc., would be affected by changing climate conditions (California's Fourth Climate Change Assessment Statewide Summary Report).

Vulnerability is the "susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt" (Adger, W.N. "Vulnerability." *Global Environmental Change*, Volume 16, Issue 3, pp. 268-281, August 2006). Vulnerability can increase because of physical (built and environmental), social, political, and/or economic factor(s). These factors include, but are not limited to race, class, sexual orientation and identification, national origin, and income inequality. Vulnerability is often defined as the combination of sensitivity and adaptive capacity as affected by the level of exposure to changing climate (California's Fourth Climate Change Assessment Statewide Summary Report).

1   EXECUTIVE SUMMARY

Southern California Edison (SCE) and its utility counterparts must continually strengthen the electric grid to prevent grid damage and minimize adverse impacts to customers from occurrences such as **earthquakes and high wind and storm events**. With the increasing risk of severe weather events as a result of climate change, including **wildfires, extreme temperatures, drought, and sea level rise**, the utility industry now must urgently bolster the grid's resilience and adaptive capacity to ensure uninterrupted power supply and customer safety.
The growing need to improve grid resilience is evidenced by recent hazard events, including:

- An increase in wildfires in California.

- High wind events: 2023 hurricanes off the coast of California and south of Hawaii (Maui wildfires and lawsuits), and 100 mph winds, also in 2023 (Magic Mountain Truck Trail).

- Extreme temperatures: 5°F projected increase in average temperature by 2050 relative to historical averages.[1]

- Sea level rise: projected 2.6-foot sea level rise by 2050 relative to the year 2000.[2]

- The continuing earthquake threat: 75% likelihood of a 7.0 magnitude or greater earthquake in the Southern California region within 30 years from 2014.[3]

SCE must maintain its entire infrastructure (50,000 square miles, 1.4 million poles, 118,000 miles of distribution and transmission lines, and more than 740,000 transformers) while adapting to the growing occurrence of hazards and new environmental design requirements. Inspections may not identify the need to increase grid hardening due to these changing design requirements. In addition, environmental conditions may amplify hazards that affect the grid's reliability, resiliency, and safety.
To meet these challenges on a wide scale, one solution (in addition to the limited capability of inspections) is to model the utility infrastructure and environment with grid resiliency tools, in enough detail, to be able to simulate extreme and high-impact hazards, and to identify high-risk infrastructure.
For these reasons, SCE undertook the Comprehensive Hazards Assessment Tool (ChaT) umbrella project. This simulation project investigated the potential of taking several open source or commercially available risk assessment and geospatial analysis tools and adding functionality to create an all-hazards risk assessment tool. Such a tool could inform needed infrastructure upgrades and hardening measures, and also improve operational practices and situational awareness capabilities just prior to the occurrence of these events or in near-real-time – in turn reducing or eliminating prolonged power outages and equipment damage.
Project deliverables for CHaT were a GIS add-on with:

- Seismic hazard risk assessment capabilities for ground motion; seismic – ground failure; landslides/liquefaction/surface rupture and off-fault deformation; and U.S. Geological Survey (USGS) ShakeCast[4] system reporting.

- Climate hazard models for extreme wind conditions, extreme precipitation, extreme temperature, coastal and riverine flooding, and sea level rise.

---

[1]   2050 Climate Exposure Trends and Potential Impacts on the Electrical System, Edison International, https://www.edison.com/clean-energy/adapting-for-tomorrow.

[2]   2050 Climate Exposure Trends and Potential Impacts on the Electrical System, Edison International, https://www.edison.com/clean-energy/adapting-for-tomorrow.

[3]   Third Uniform California Earthquake Rupture Forecast, U.S. Geological Survey, https://pubs.usgs.gov/fs/2015/3009/.

[4]   https://usgs.github.io/shakecast/.

The Grid Resilience Intelligence Platform (GRIP) – a grid simulation software tool (platform) to support climate adaptation planning and wildfire risk mitigation – also was evaluated as part of the CHaT project. This tool includes:

- Pole and wind vulnerability modeling capabilities.

- Conductor-vegetation, heat, and wind risk assessment modeling capabilities.

The CHaT project successfully demonstrated the integration of hazard assessment tools and consolidation of data sources to improve grid vulnerability analysis capabilities. The project team demonstrated a new and innovative approach that integrates emerging and mature hazard assessment tools using a centralized data architecture – versus the current practice of needing to utilize disparate data – with various types of SCE asset data from non-electric, generation, and grid infrastructure.

In addition, the GRIP portion of the project successfully demonstrated the integration of hazard assessment tools and consolidation and compatibility of SCE data sources to support additional vulnerability assessment capabilities. If/when completely validated at scale, the CHaT and GRIP tools could identify high-peril infrastructure conditions and inform needed infrastructure upgrades to mitigate the strong risks identified with the project's simulation scenarios.

Overall, these capabilities would improve SCE's and the California Public Utilities Commission's (CPUC) understanding of the electric system's vulnerabilities to natural hazard events by assisting with risk assessments and identifying grid vulnerabilities that can be documented with SCE's future vulnerability assessment filings.

2   PROJECT SUMMARY

Many of the physical grid models currently used for assessments have been formulated in a complex "hidden black box" software environment. Today the opportunity exists to validate existing modeling and simulation tools by generating complementary vulnerability assessments, as (for example) in the case of substation earthquake risk. However, a complete simulation tool does not exist for high wind events that affect reliability, wildfire risk, and public safety. While there are some tools that model and simulate part of the entire hazard environment, most of them have not been validated, and a complete end-to-end toolchain does not exist in many cases.

Within this context, SCE's ChaT umbrella project focused on evaluating two innovative grid resiliency tools, both utilizing a centralized data architecture, to perform vulnerability assessments and inform hazard mitigation efforts for 1) substation earthquake risk, and 2) low-voltage distribution infrastructure risk from high winds. In addition, several climate hazards were analyzed and projected (sea level risk, extreme precipitation, temperature, earthquake, and high winds) in terms of frequency and severity of damage through 2070, to create additional models for SCE's service territory and establish a more complete hazard toolset for the industry.

The GRIP tool used in the project was created by the U.S. Department of Energy's (DOE) SLAC National Accelerator Laboratory. It is an end-to-end physical infrastructure and power system modeling resiliency software platform that models poles, conductors, and vegetation, as well as interactions and dynamics with the environment (e.g., wind, ambient extreme heat, loading increased current).

In addition, GRIP evaluates the effect on power system reliability (System Average Interruption Duration Index, SAIDI), with the potential reduction of Public Safety Power Shutoff (PSPS)[5] thresholds and affected customers in red flag warning situations. The project evaluation included assessment of cyber risk, integration with SCE data, and validation of critical functionality. Additional testing and validation for GRIP is continuing using separate funding from the DOE, with anticipated completion in Q4 2024.

---

[5]   https://www.sce.com/outage-center/outage-information/psps

2.1 Electric Program Investment Charge

SCE's CHaT project, including the GRIP evaluation, supported the CPUC's Climate Adaptation Rulemaking. As part of the rulemaking, all utilities are required to perform an assessment to understand electric system vulnerabilities in the event of hazards brought on by climate change.

The project was implemented through the CPUC's Electric Program Investment Charge (EPIC) III program[6]. EPIC supports the development of new, emerging, and pre-commercialized clean energy innovations in California. These projects must be designed to ensure benefits in the form of equitable access to safe, affordable, reliable, and environmentally sustainable energy for electricity ratepayers. EPIC consists of three program areas: Applied Research and Development (Applied R&D), Technology Demonstration and Deployment (TD&D), and Market Facilitation.

Per the EPIC Investment Framework for Utilities (Figure 1), the CHaT project (with GRIP) supported the guiding principles of Safety, Reliability, and Affordability by addressing the challenges faced by the grid infrastructure due to natural hazards. Expected benefits of adopting the project technology at scale include:

- Enhanced reliability, lower costs, and improved safety via a tool that can inform optimal design and mitigation to make the grid more resilient to natural hazard events/disasters.

- Ability to more quickly and accurately respond to natural disasters through heightened situational awareness, thereby minimizing impacts on customers.

- Reduced repair frequencies and durations by hardening the grid where hazards are most likely to occur.

- Mitigation of loss and damage resulting from hazard events, as well as the ability to more efficiently initiate recovery efforts.

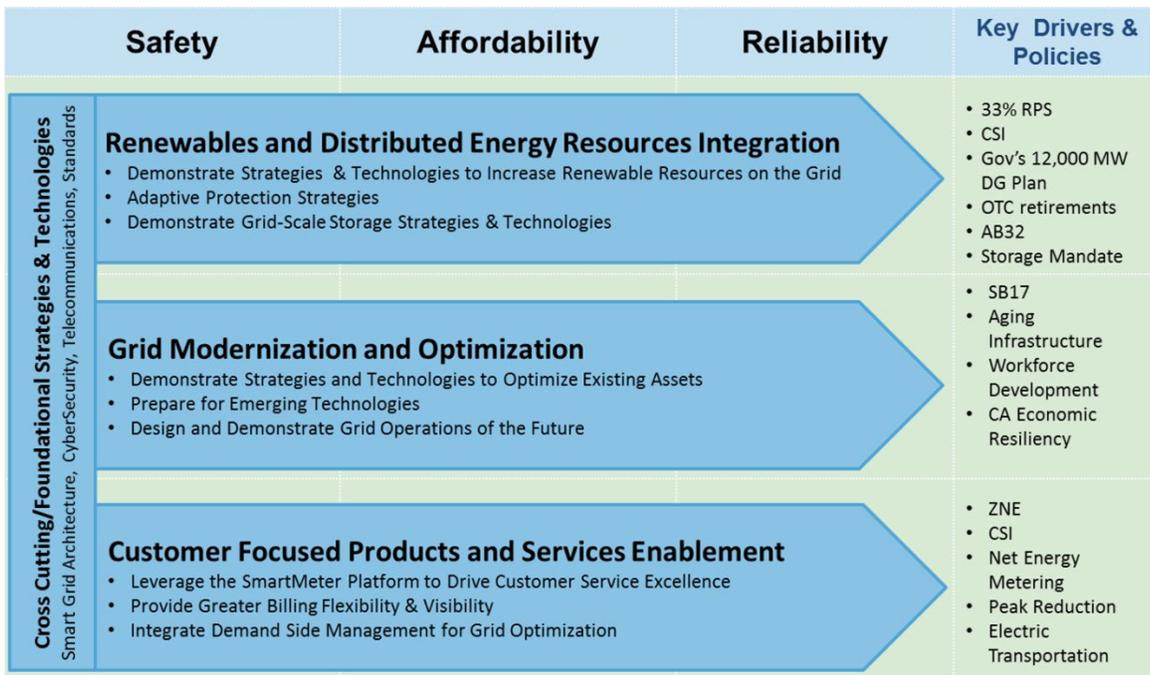- Potential savings via reduced operational/maintenance and capital investment costs.

Figure 1. EPIC Investment Framework for Utilities

---

[6]   EPIC III – SCE 2018-2020 Investment Plan Application. A17-050005. https://www.sce.com/regulatory/epic/regulatory-filings.

2.2 Standards

There are no standards in place for natural hazard risk assessment. Industry standards are needed for natural hazard risk models and component fragilities. A methodology for natural hazard risk assessment should be standardized as well.

2.3 Problem Statement

SCE's grid infrastructure faces a large and growing number of physical hazards such as earthquakes and climate-related extreme weather events. However, SCE's risk assessment capabilities are fragmented by disparate data sources required for vulnerability analysis. Centralization and optimization of planning and operations capabilities for hazard mitigation and response are required to enhance effective responses during these events. To help address this issue, the CHaT project focused on demonstrating a new and innovative approach to integrate emerging and mature hazard assessment tools.

2.4 Confidential Information

Confidential information that is not included in this report includes critical/sensitive infrastructure data such as that regarding SCE electrical facilities.

2.5 Project Scope

CHaT, the GIS add-on tool assessed in this project, integrates various types of asset data from non-electric, generation, and grid infrastructure sources to provide decision support on hazard impact and mitigation options before, during, and after a significant event (e.g., earthquakes, extreme weather events, wildfires, etc.).
It also incorporates hazard risk assessment/severity index capabilities to allow a comprehensive assessment of vulnerability and exposure across SCE's service territory. (See Appendix 4.1, Potential Impacts for Climate Hazards, for a summary of climate hazard impacts on SCE electric system assets.)
More specifically, the tool includes the establishment of an electric utility component database of fragilities (based on known fragilities), the Federal Emergency Management Agency (FEMA) "Seismic Assessment Performance of Buildings" P-58,[7] Global Earthquake Model (GEM), and hazard fragility functions. Seismic hazard modules – shown in Figure 2 below – allow probabilistic and deterministic simulation capabilities for substation components, distribution poles, and transmission towers using **Open-Source Seismic H**azard **A**nalysis (OpenSHA)[8] and the USGS ShakeMap[9] API.[10] (See Section 2.5.1.1, Evaluation with OpenSHA, for more details on this particular component.) Climate hazard modules for extreme wind, precipitation, temperature, sea level rise, and flood hazard events use SCE's climate models and Cal-Adapt[11] climate projections.

---

[7]   https://www.fema.gov/sites/default/files/documents/fema_p-58-2-se_volume2_implementation.pdf.

[8]   https://opensha.org/.

[9]   https://earthquake.usgs.gov/data/shakemap/.

[10]   https://earthquake.usgs.gov/fdsnws/event/1/.
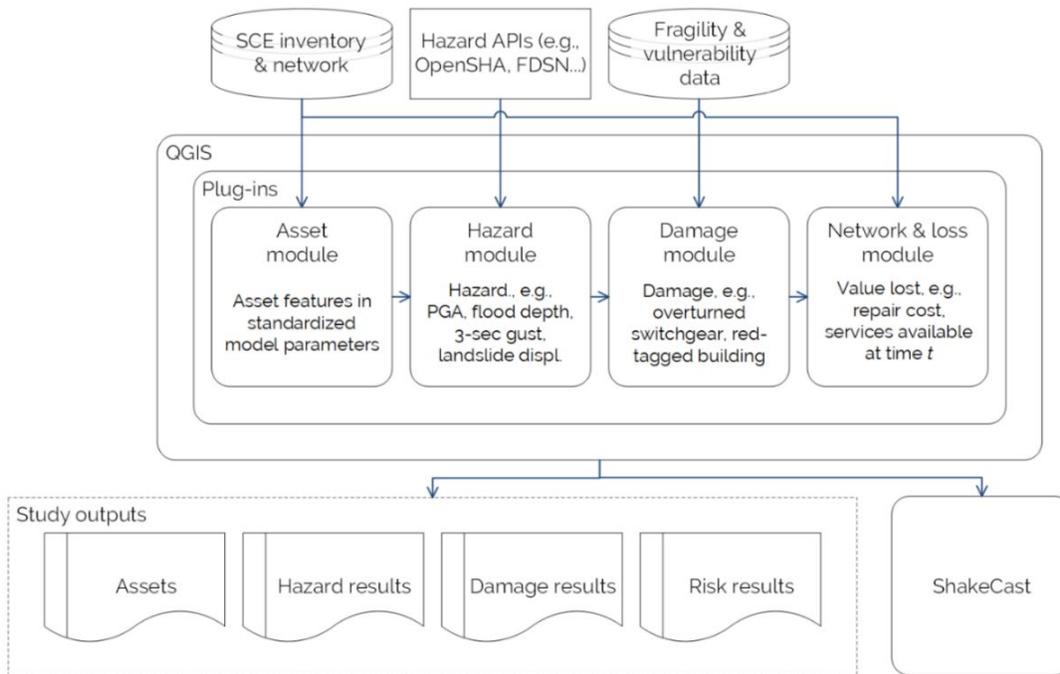
[11]   https://cal-adapt.org/.

Figure 2. CHaT Seismic Hazard Analysis Features

Figure 3 provides an overview of the full CHaT tool, with more detailed information in subsequent sections on the project demonstration work.

Figure 3. Hazards Incorporated into the CHaT Tool

	Seismic	Flooding	Precipitation	Temperature	Wind
Description	A model that estimates seismic damage based on asset fragilities (actual or estimated)	A model that estimates the percent damage as a function of flooding depth	A model to reflect potential future increases in extreme rainfall events and long-term precipitation trends	A model that reflects historic events and damage and can be run to reflect potential future increases in temperature	A model that shall provide forecasts of future storms, factoring in SCE historic data trends and an allowance for ongoing climate change
Data	• Substation Assets • Transmission Towers • Distribution Poles • Generation Facilities • Historical Damage • Known Fragilities	• Substation Assets • Transmission Towers • Distribution Poles • Historical Damage	• Substation Assets • Transmission Towers • Distribution Poles • Historical Precipitation • Historical Damage	• Substation Assets • Transmission Towers • Distribution Poles • Historical Temps • Historical Damage	• Substation Assets • Transmission Towers • Distribution Poles • Historical Wind • Historical Damage

Deliverables	• Asset Module
	• Seismic Module
	  o Seismic Engine
	  o Damage Module
	  o Network & Loss Module
	  o ShakeCast Module
		• Sea Level Rise Model
		• Flooding Model
			• Extreme Precipitation Model	• Extreme Temperature Model	• Wind Model

2.5.1 Seismic Hazards Evaluation for Substations

In this portion of the project, multiple iterations of a CHaT simulation were used to analyze system damage for seismic hazards. For each iteration, one realization of the ground motion was created by applying uncertainty to the median peak ground acceleration (PGA).

For substations, the damage state was modeled solely as a function of ground shaking. The failure probability for each substation component was determined using associated fragility functions. The substation loss of function was determined by the loss of function of one or more substation transformers.

The towers and poles supporting transmission/sub-transmission lines also were analyzed. A failure was assigned if a landslide occurred and exceeded 80 cm or if liquefaction occurred. Tower failure results in supporting circuit lines becoming nonfunctional, so once the nonfunctional circuit lines were determined, network analysis was conducted to identify those substations that were no longer receiving power from the source (meaning they were considered nonconnected).

2.5.1.1 Evaluation with OpenSHA

From "Hazard Calculations for the WGCEP-2022 Earthquake Forecast Using OpenSHA and Distributed Object Technologies" (Field, E.H. et al., *Seismological Research Letters*, March/April 2005):[12]

[Open-Source Seismic Hazard Analysis] (OpenSHA) (Field et al., 2003) is a collaborative effort between the [Southern California Earthquake Center] (SCEC) and the United States Geological Survey (USGS) . . . to develop a "community modeling environment" or "collaboratory" for seismic hazard analysis (SHA), where any arbitrarily complex model component can be plugged in for analysis (without having to change what is being plugged into).

The basic OpenSHA framework and computational sequence are illustrated in [Figure 4]. The two main model components are an Earthquake-Rupture Forecast (ERF), which gives an inventory of all possible earthquake-rupture events in the region, and their associated probabilities, over a specified time span and above some magnitude threshold; and an Intensity-Measure Relationship (IMR), which gives the probability that some Intensity Measure Type (such as peak ground acceleration) will exceed a specified value at a site given the occurrence of an earthquake-rupture event.

[The ShakeMap module is able] to produce maps for any one of the hundreds to tens of thousands of ruptures defined in the [Working Group on California Earthquake Probabilities] (WGCEP-2002) model (exact numbers depend on parameter settings), any one of the more than 1,000,000 ruptures defined for California in the 2002 National Seismic Hazard Map model (Frankel et al., 2002), or any custom "hand built" rupture [based on a custom IMR for the calculation].

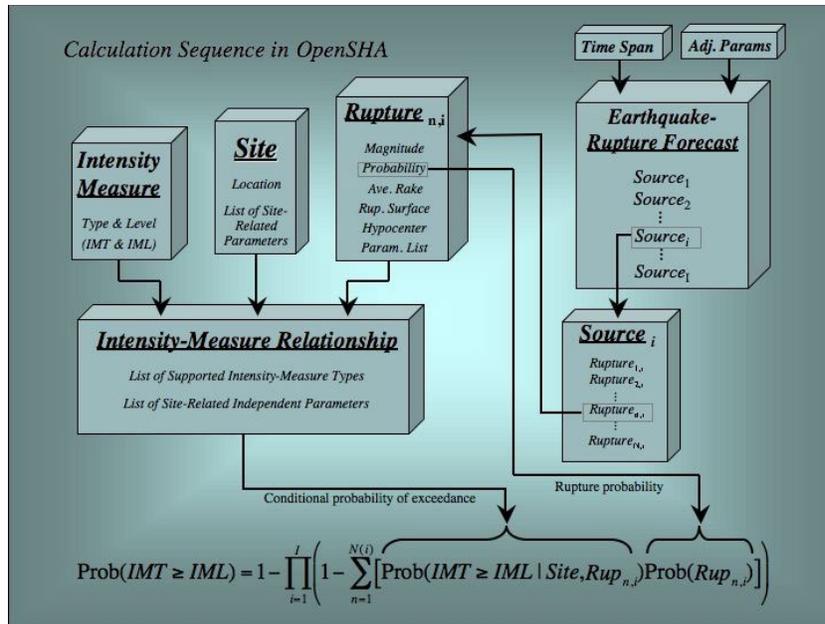[12] https://opensha.org/resources/Field_2005_SRL.pdf.

Figure 4. Calculation Sequence in Open-Source Seismic Hazard Analysis (OpenSHA)[13]

2.5.2 Climate Hazards for Assessments of Utility Assets

For each climate hazard – flooding (including sea level rise), extreme precipitation, extreme temperature, and wind – the project team analyzed the modeled frequency and severity of extreme events, in the past and projected through 2070, to create models relative to SCE's service territory. This work included synthesis of data from internationally accepted models and government agencies, informed by academic research. Details are provided for each hazard in the following sections. See Appendix 4.2 for data sources used to create these models.

2.5.2.1 Flooding

Storm events, sea level rise, and inland flooding pose a risk to inland and coastal power plants. Flood risks to electricity generation result from the need for most thermoelectric plants to be close to sources of cooling water. In recognition of this, the U.S. utility that serves Massachusetts, New York, and Rhode Island (states that suffered unprecedented damage from Hurricane Sandy in 2012) has begun upgrading vulnerable transmission substations to be able to withstand a 1,000-year flood event.

FEMA has developed default fragility curves for substations and distribution circuits for use in its hazardous loss estimate/risk assessment model. These curves estimate the percent damage as a function of flooding depth. For example, a damage level of 100% would require the complete replacement of the facility. Some research also has focused on the risks to underground transmission and distribution systems from flooding and sea level rise.

Climate change can escalate the severity of floods by increasing the severity of precipitation runoff due to dry soil that absorbs moisture poorly, and by increasing the likelihood of rapid snowpack melt. Other human-related factors such as constrained river flows, addition of impermeable surfaces like pavement, and deforestation also contribute to flooding risks. In addition, climate change is causing sea level rise due to melting ice sheets and thermal expansion of warmer ocean water, intensifying both the depths of storm surges and coastal inundation during high tides. The flood model used in the CHaT project combines information about the probability and depth of four types of floods: coastal high tide flooding, storm surge, fluvial (riverine), and pluvial (surface) flooding.

---

[13]   Source: Field, E.H. et al. "Hazard Calculations for the WGCEP-2022 Earthquake Forecast Using OpenSHA and Distributed Object Technologies." *Seismological Research Letters*, March/April 2005. https://opensha.org/resources/Field_2005_SRL.pdf.

Coastal Flooding

The sea level rise model is based on climate projections for high tides and storm surges (which are the additional water movement above tides caused by high winds). In addition, the model factors in the number of days per year projected to have inundation, based on elevation and observed and projected data for local flood gauges. It also uses the Maximum Envelope of Water (MEOW)[14] outputs from storm surge flood modeling from the National Hurricane Center (NHC) and Central Pacific Hurricane Center (CPHC).

Inland Flooding

Flooding risks away from the coast include fluvial flooding – when a river, lake, or other body of water overflows – and pluvial flooding – meaning surface flooding due to intense rain or runoff. The CHaT project assessed fluvial flood risk using a random forest model that extends FEMA flood risk zones across the entire U.S. and computes flooding depths. The flood model uses the projected change in 6-hour rainfall extremes, elevation, land cover, and soil characteristics to forecast extent, probability, and depth of potential surface flooding.

2.5.2.2 Precipitation

Rising temperatures increase water vapor in the atmosphere by increasing evaporation, and because warmer air can hold more moisture. While total yearly precipitation may increase or decrease depending on the region, climate models agree that the precipitation that does occur will become more severe. The CHaT precipitation model uses the number of the wettest events annually projected for years around 2070, and the amount of projected rain in these storms. The project team looked at historical conditions (1980-2005) in the Southern California area and defined a threshold of two days exceeding the top 1% of total precipitation in a year as the wettest events.

2.5.2.3 Extreme Temperature

In this portion of the project, the team evaluated the impacts of an extreme heat event.

Transformers and power lines are particularly vulnerable to high ambient air temperature. Persistent extreme temperatures can lead to deratings, shorter lifetimes, and abrupt failure of these components. The response of efficiency and maximum capacity of power transformers to ambient temperature is usually represented as a linear relationship with varying inclinations (e.g., slopes). In general, the average power output decreases 0.7% to 1% per 1°C increase in air temperature above a reference temperature (usually taken to be 20°C).

High temperatures also increase transmission and distribution line losses and reduce carrying capacity. Average electricity transmission and distribution losses are about 5% in the U.S. The resistance of power lines increases with temperature, leading to greater resistive loss; however, the impact of ambient temperature on resistive losses is generally considered to be negligible compared to impacts on total carrying capacity. The line capacity is limited by the maximum normal operating temperature, typically 80°C. The operating temperature of the line depends on several factors (including the ambient temperature, current in the line, and wind speed), which affects the ability of the line to get rid of excess heat and is generally much higher than the ambient temperature. (The Institute of Electrical and Electronics Engineers (IEEE) Standard for Calculating the Current-Temperature of Bare Overhead Conductors (IEEE 738-2006)[15] gives line operators a method for modeling transmission line temperature.)

In addition, higher line operating temperatures can cause excessive sag of power lines due to thermal expansion. Sagging power lines pose many risks, including fire and safety hazards, and increased chance of lines contacting trees or the ground. In order to avoid excessive sag and maintain operating temperatures within design limits, system operators may manually reduce line capacity. For example, a California Energy Commission (CEC) study found that an ambient temperature of 37.78^{o}C resulted in 7%-8% capacity loss below normal design ratings.

2.5.2.4 Wind

Most work on electricity generation vulnerability to wind has focused on wind turbines. Wind turbines are vulnerable to hurricanes because the maximum wind speeds in these storms can exceed the turbines' design limits.

---

[14] https://www.nhc.noaa.gov/surge/meowOverview.php.
[15] https://ieeexplore.ieee.org/document/4085389?denied=.

Failure modes can include loss of blades and buckling of the supporting tower. In many areas being actively considered by developers of offshore wind farms, for instance, nearly half of the turbines in a given farm are likely to be destroyed in a 20-year period. The distribution of the number of wind turbine towers buckled by hurricanes can be modeled using parameters estimated as combined probabilities of multiple single wind turbine tower buckling along with the probability of an area receiving winds of hurricane magnitude.

Regarding the overall electric system, high winds can snap towers and down power lines, causing widespread electricity customer outages. A variety of fragility curves and statistical methods have been developed for analyzing past power outage data during adverse weather events to identify recurrent patterns in the power outage data in order to understand the existing power grid's vulnerability. For example, fragility curves have been constructed to characterize, during hurricanes, the relationship between wind speed and resulting power outages. For these curves, real-time power outage data and wind speed data are used to derive statistical relationships. These 'as-built' relationships are then compared to the 'as-designed' engineering fragility curves to improve risk assessment and outage forecasting during future high wind events.

The physical response of towers and power lines to high winds is commonly represented as a function of line failure probability in response to wind speed. These fragility curves are usually taken to be a lognormal distribution, where the probability of being in, or exceeding, a damage state ds is described by the lognormal function:

$$P[ds|S_d] = \Phi\left[\frac{1}{\beta_{ds}} ln\left(\frac{S_d}{\bar{S}_{d,dx}}\right)\right]$$

In this function, $\bar{S}_{d,dx}$ is the median value of engineering parameter (e.g., displacement or stress) at which the tower or power line reaches the threshold of the damage state ds; β_{ds} is the standard deviation of the natural logarithm of engineering demand parameter at which the asset reaches the threshold of the damage state ds; and Φ is the standard normal cumulative distribution function. This type of fragility curve also can be used to characterize damage in response to other hazards (e.g., earthquakes) or to other kinds of infrastructure. In 2007, a large energy company used an empirical fragility curve showing the probability of pole failure based on wind speed and pole type (wood, concrete, lattice steel, or tubular steel) to address potential damage to distribution poles from projected hurricane events. The company further calculated direct costs of damage to the poles based on the number affected.

2.5.3   Grid Resiliency Demonstration Platform (GRIP)

Used to enhance the CHaT model, the GRIP portion of the project demonstrated a novel suite of software simulation tools for anticipating extreme wind events and improving grid resiliency.

GRIP is primarily a grid physical wind impact analysis simulation tool focused on improving grid resiliency, where grid resiliency is defined as improving the ability to withstand extraordinary and high-impact, low-probability events (some never experienced before). If implemented at scale, the GRIP platform could inform strategies (such as for operational practices, situational awareness, and grid hardening) for climate adaptation and mitigation of fire-ignition, reliability, and safety risks.

The main differentiator and value-add of GRIP compared to related industry tools is that GRIP is an integrated wind asset and power system simulator tool that can model and quantify 1) physical and electrical vulnerability (power flow modeling) relative to current asset health, and 2) the environment's effect on physical assets (e.g., increase in current and conductor elongation due to extreme heat and greater customer usage, such as for air conditioning). See Figure 5 for the GRIP value proposition process.

The GRIP demonstration included two main use case categories:

- Simulating and evaluating distribution wood pole performance under extreme wind conditions to assess performance of poles for informing climate adaptation strategies.

- Simulating and evaluating wind-caused primary conductor contact with vegetation under extreme wind conditions to assess performance of conductors, inclusive of:

- Ambient temperature/extreme heat influence on conductor elongation.

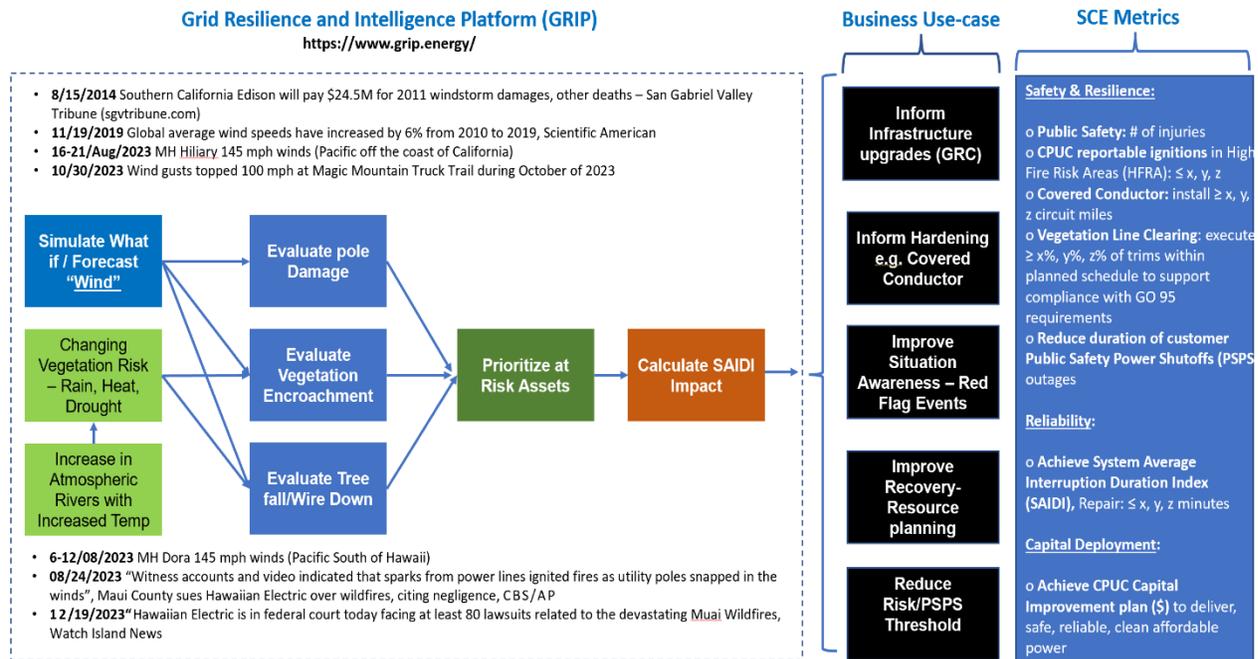- Increased loading due to temperature/extreme heat influence on conductor elongation.

Figure 5. GRIP's Value Proposition Process for High-Wind Vulnerability Mitigation

2.5.4   Cybersecurity

In accordance with SCE cybersecurity standards, policies, and industry standards, the CHaT project needed to develop a robust cybersecurity strategy and incorporate and integrate applicable technologies and techniques to best secure these systems. Security measures were identified and applied as necessary to ensure the successful operation of the project goals and objectives.

Additionally, SCE's Cybersecurity team provided architectural, engineering, and other support to evaluate potential areas of concern. In each phase of the project, all inputs and documentation were examined, compiled, and used to create cybersecurity evaluation and testing plans. The Cybersecurity risk team evaluated the risk associated with program components, design, or intended usage, while engineering ensured that the design and integration of cybersecurity practices and technology would not adversely impact the project's goals. The cyber testing evaluation included compliance, security, and functionality without impacting the project's functionality and operations.

The cyber testing plan illustrated what needs to be used during testing to establish project expectations and requirements. This testing encompasses evaluating the project's data protection, authentication, encryption, vulnerability, and other relevant areas that are determined during each project phase. Through the project lifecycle, these holistic approaches to security are paramount to ensuring reliability, integrity, and confidentiality.

2.6 Schedule and Milestones/Deliverables

Despite minor delays in achieving some milestones, the project was successfully completed within the expected timeframe.

Deliverable Name	Start Date	End Date
Implementation Strategy	03/22	08/22
Asset Module (Data Engineering)	08/22	10/22
Hazard Module: Shaking	03/22	6/22
Hazard Module: Ground Failure	03/22	7/22
Damage Module	09/22	12/22
Network and Loss Module	09/22	02/23
ShakeCast	03/22	06/22
Extreme Precipitation Hazard Model	11/22	12/22
Extreme Temperature Hazard Model	07/22	08/22
Sea Level Rise/Flooding Hazard	01/23	02/23
Wind Hazard Model	02/23	08/23
Technical Documentation and Closeout	03/23	08/23

Table 2. CHaT Project Schedule and Deliverables

Deliverable Name	Start Date	End Date
Planning, Grid Services, Cyber Engineering, and Testing	2/2/22	7/23/23
Set-up, Install, and Test Environment (Server and Software): Resolve Issues; Identify, Gather Data and Integrate; Test Software	1/5/23	12/31/23
Circuit Conversions and Test Workflow (Pole Vulnerability Module, Tree-Fall/Vegetation Contract Module, Power Flow Analysis Time-Series Integration Module n, SAIDI/CAIDI Economic Analysis Module, and Preliminary Validation Use Cases (Sprint 1 and 2)	7/26/23	3/15/24

Table 3. GRIP Project Schedule and Deliverables

3   PROJECT RESULTS

Once all project iterations were completed, mean and standard deviation statistics were calculated for substation failure, downed circuit lines, and power outages. The results showed that CHaT is a feasible tool to use for planning and operational seismic studies. However, the impacts of climate- and weather-related events are not easily quantified for electric utility assets. Transmission and distribution lines and substations are at risk of damage from flooding, sea level storm surge events, extreme wind, precipitation, and temperature.

This project integrated existing infrastructure component vulnerability information (known fragilities at SCE) with component fragility curves (Hazus Earthquake Model Technical Manual),[16] as well as incorporated climate change projection data (Cal-Adapt), to understand risk from a primarily empirical and single-event-driven approach. The ability to perform a comprehensive assessment of cumulative damages from multiple extreme weather and climate events to specific and multiple components of the electric grid requires further study and evaluation. As the frequency and intensity of extreme weather and climate events are expected to rise in the future, understanding the sensitivity of specific components of electricity systems and their collective vulnerability to climate and weather hazards is crucial to long-term planning. Therefore, additional efforts will be required to further enable such capabilities.

That said, overall, the CHaT project did successfully demonstrate the integration of hazard assessment tools and consolidation of data sources to improve the grid's vulnerability analysis capabilities.

The following summarizes results of the CHaT component simulations:

Seismic Hazards

The hazard map (Figure 6) shows the probability of failure for electrical substations based on the project evaluation. The red line represents the selected rupture (fault line). The colors correlate to the failure probabilities in the map legend.

---

[16] https://www.fema.gov/sites/default/files/2020-10/fema_hazus_earthquake_technical_manual_4-2.pdf.
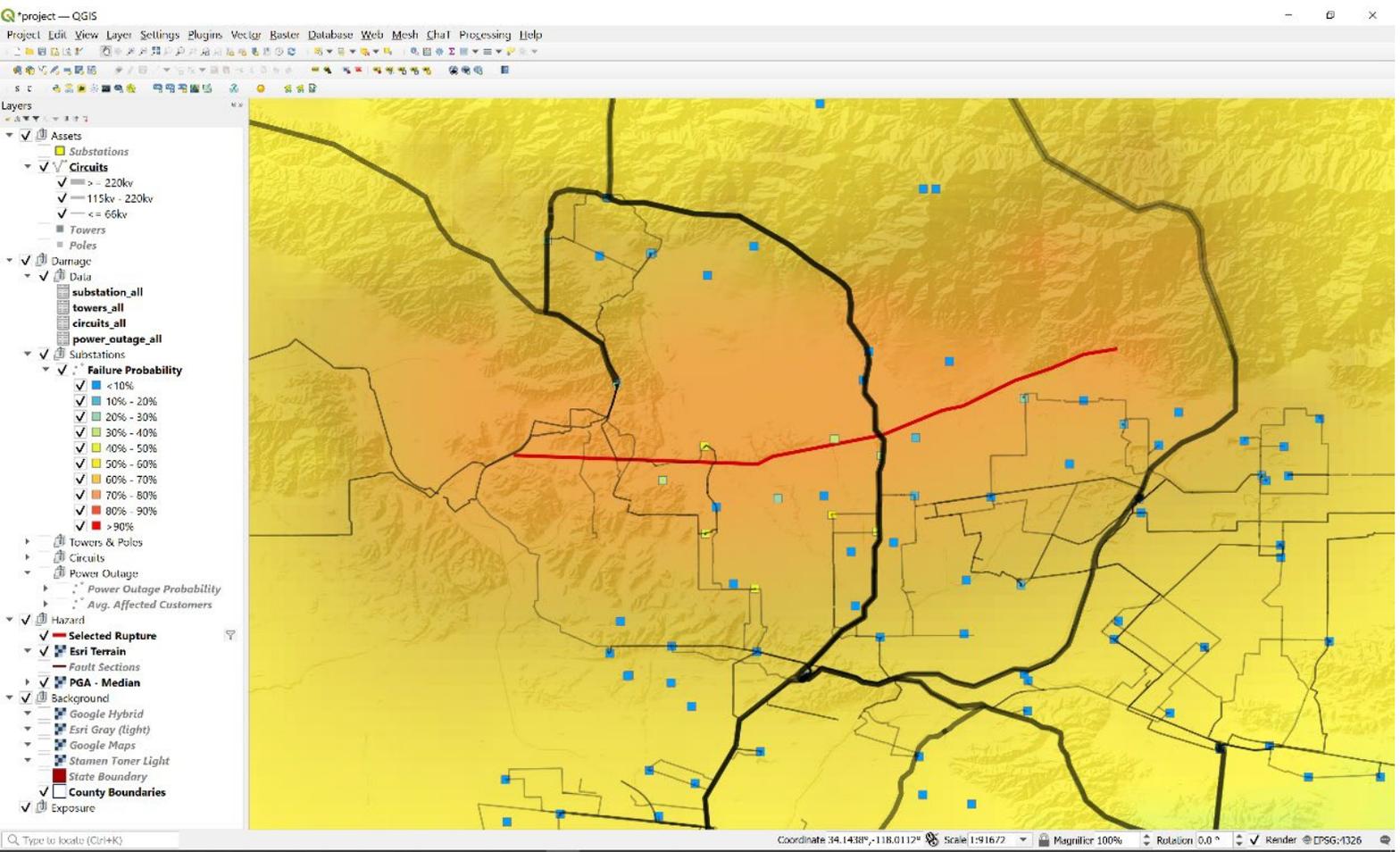
Figure 6. Screenshot of CHaT Seismic Scenario Results

Following are specific findings on the overall estimated impact for each seismic scenario as a systemwide total.

- Average systemwide total number of nonfunctional substation components: 593.47 (standard deviation: 532.29)

- Average systemwide total number of nonfunctional T and S substation transformers: 1.57 (standard deviation: 1.69)

- Average systemwide total number of nonfunctional D substation transformers: 11.66 (standard deviation: 13.61)

- Average systemwide total number of nonfunctional substations: 23.57 (standard deviation: 22.39)

- Average systemwide total number of failed transmission towers and poles: 6.23 (standard deviation: 6.91)

- Average systemwide total number of nonfunctional transmission lines: 7.55 (standard deviation: 7.54)

- Average systemwide total number of substations with power outage: 82.11 (standard deviation: 48.07)

- Average systemwide total number of customers affected by power outages: 509,887.99 (standard deviation: 354,352.19)

Flooding

In general, underground power lines have a shorter useful life and are more susceptible to corrosion than overhead lines. Water from inundation or flooding may follow electrical lines back to underground conduits and vaults,

damaging underground substations, and underground wires also can be vulnerable to damage from saltwater intrusion associated with sea level rise. However, quantitative fragility curves for underground lines are limited.

The project included default fragility curves for three types of substations and three types of distribution circuits as a function of flood depth.

Figure 7. Screenshot of CHaT Flooding Scenario Results

Extreme Temperature

California, the most populous and third-largest U.S. state, has a diverse climate. Due to the moderating effect of the Pacific Ocean, coastal locations experience mild year-round temperatures, while inland locations experience a wider range of temperatures. Because of California's large north–south extent and the existence of several mountain ranges, extreme climate events often affect only a portion of the state. The screenshot below depicts the results for an extreme heat event based on the project analysis.
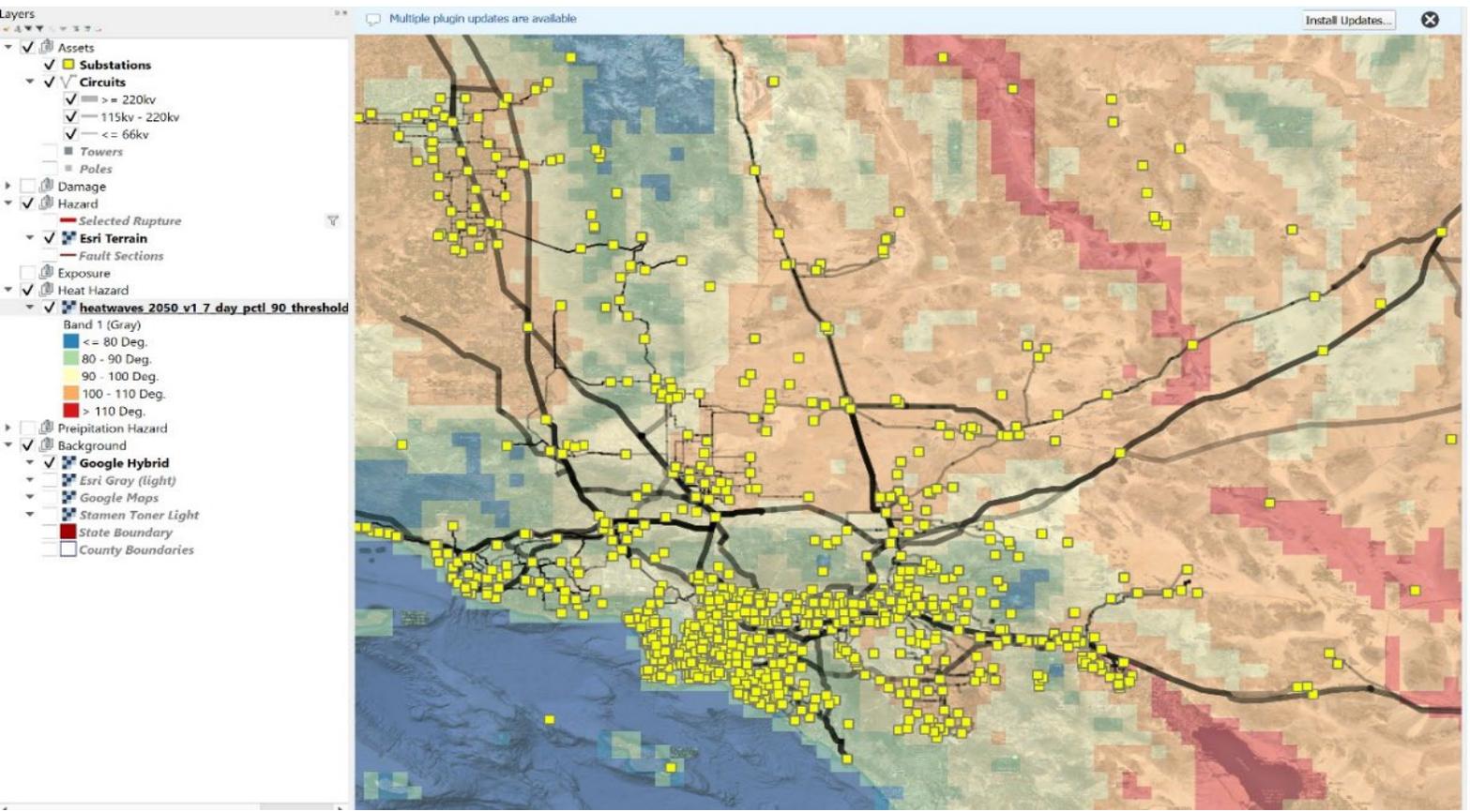
Figure 8. Screenshot of CHaT Extreme Temperature Scenario Results

Precipitation

Extreme precipitation events resulting in damaging flooding occur periodically. In particular, atmospheric rivers, a weather phenomenon in which a narrow band of very moist air is transported from tropical latitudes of the Pacific Ocean to the West Coast, can cause torrential rainfall. The screenshot below depicts the results for a 100-year extreme precipitation event.
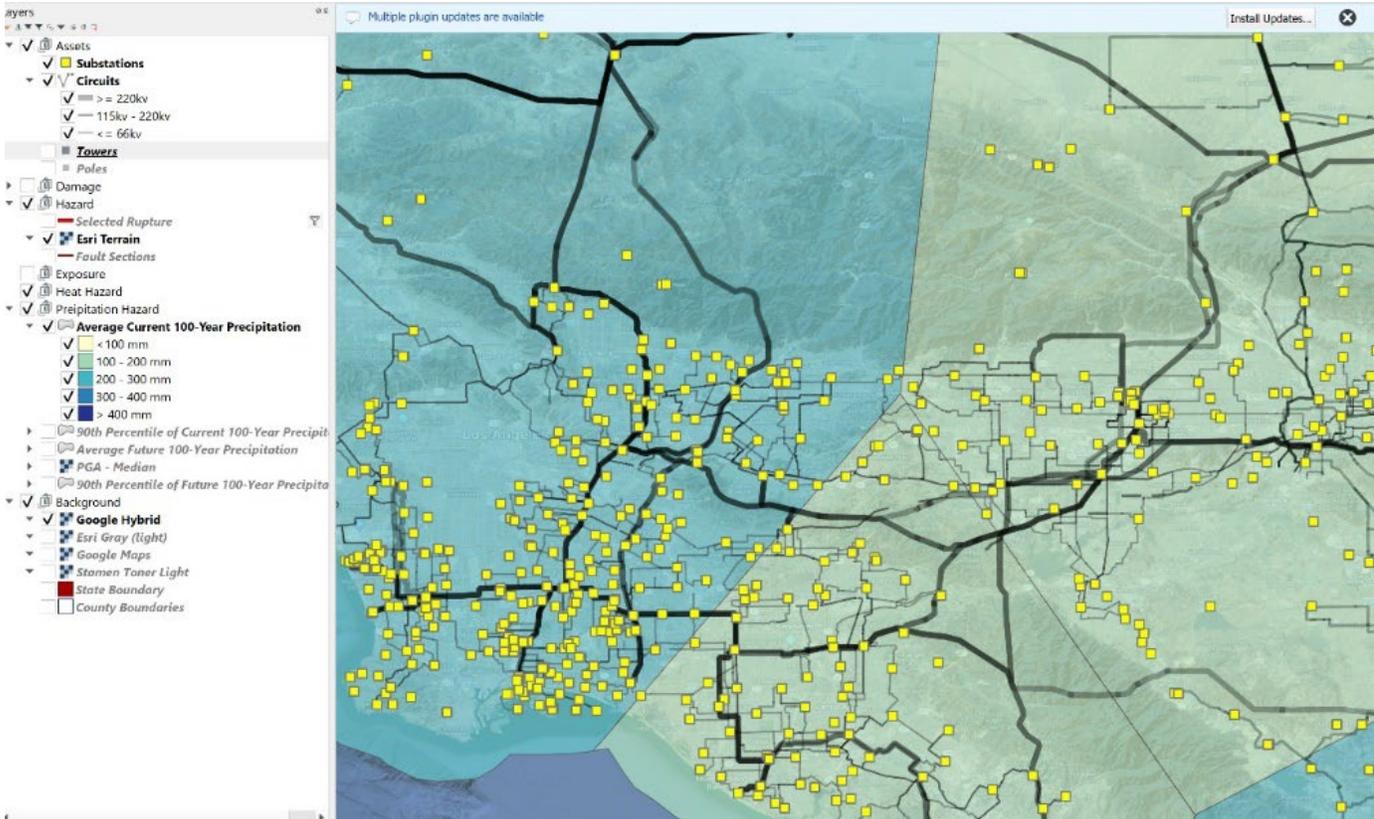
Figure 9. Screenshot of CHaT Extreme Precipitation Scenario Results

Wind

Here is power line wind fragility from empirical results (1) and engineering curve (2):

$$y = 4.732e\ 0.048x\ (1)$$
$$y = 5.1519e\ 0.0546x\ (2)$$

Y = percent of county customers without power, and x = 1-minute maximum wind gusts (in knots) at the nearest measurement station.

The CHaT project also included evaluation of GRIP – primarily a grid physical wind impact analysis simulation tool focused on improving grid resiliency. The following section includes results of this evaluation.

3.1 GRIP Project Component Results

This GRIP software platform was successfully deployed in the lab environment at SCE and integrated with internal SCE tools. It also passed the cyber risk assessment. Key capabilities included:

- Reduced order physics-based hybrid modeling of poles and interaction with the environment (extreme wind, physical connections) and the power system.

- Reduced order physics-based modeling of conductors and interactions with the environment (extreme wind, physical connections, vegetation, extreme heat – elongation of conductors, extreme heat – increase in current due to air conditioning load) and the power system.

Specific findings included:

- In assessing broken pole events, the project team found that poles failed under two distinctly different wind conditions: 1) an increase in wind speed from 5 to 42 mph in about 6 hours, and 2) sustained wind speeds from 25 to 42 mph over 36 hours.

- For the events and circuits selected for high-wind events (1/19/2021 to 1/21/2021) resulting in pole failures, the team observed that many of the failures occurred in an approximately 80 square-mile area, and at wind speeds just below wind design speeds of 48 to 56 mph (~42 mph). (These were recorded wind speeds from the closest weather station. Actual wind speeds at the pole locations could have been different.)

- Based on the overall project results, the team considers the prioritization of pole failures as more important than wind speeds of actual fail in terms of identifying high-risk poles for inspection or immediate replacement. The wind speed of failure is second in importance, but not critical for prioritizing high-risk poles.

Continued GRIP validation work, and further investigation into reducing Public Safety Power Shutoff (PSPS) thresholds, is continuing under the DOE Grid Modernization Lab Consortium (GMLC) project, with reporting planned for Q4 2024.

3.2 Scalability

ChaT shall be scalable for use in production-scale demonstrations and the Enterprise Analytics platform using SCE standardized tools. To ensure the transferability and scalability of CHaT, a comprehensive technology transfer plan was established.
GRIP was originally created on the Google Cloud Platform (GCP) and can be deployed on GCP to scale its simulation to a large utility territory.

3.3 Value Proposition

This project supported the following elements of SCE's Strategy, Planning & Operational Technology (SPOP) Technology Roadmap:

- **Strategic Pillar**: Operational and Service Excellence

- **Objective:** Enable more data-driven decision-making to improve quality, accuracy, and efficiency of operations and customer service.

- **Capability:** Provide suite of data analytics solutions to meet business needs.

Overall, the project demonstrated and enabled the achievement of the strategic objective by demonstrating (in a lab environment) an effective means to enhance the grid's vulnerability analysis capabilities. If implemented at scale, this could help in identifying areas of needed improvement and in implementing effective risk mitigation measures. See the next section (3.4, Metrics), for more details on the benefits/value of adopting the project technology at scale.

3.4 Metrics

The following project metrics were identified for the CHaT project:
Safety, Power Quality, and Reliability (Equipment, Electricity System):

- *Outage number, frequency, and duration reductions:* Successful demonstration of the CHaT tool's hazard mitigation and response capabilities indicates its potential to enable SCE to both improve grid resiliency and more quickly and efficiently respond to hazard events through heightened situational awareness. In real-world situations, these capabilities could lessen or eliminate prolonged power outages and equipment damage. In addition, use of the GRIP tool could reduce outage risk and duration by identifying which poles and conductors to harden and where to stage field crews to improve recovery and restoration after a high-wind event.

- *Public and utility worker safety improvement and hazard exposure reductions:* By enabling SCE to improve grid resiliency and more quickly respond to hazard events under real-world conditions through heightened situational awareness, CHaT and GRIP also could: 1) reduce public exposure to energized equipment and hazardous situations (including wildfires), and 2) lessen the need for workers to respond to/work on damaged equipment in hazardous conditions. In addition, GRIP could help reduce the risk of catastrophic wildfires and injuries by providing another tool to help SCE execute its Wildfire Mitigation Plan (WMP)[17] and programs. Quantifiable metrics in this area include (but are not limited to) Customer Minutes of Interruption (CMI) time, amount of covered conductor installed, and amount of vegetation line clearing completed.

3.4.1 Additional Customer and Infrastructure Metrics

Adoption of the CHaT and GRIP technologies at scale could provide several quantifiable ratepayer (customer) benefits and reduce infrastructure costs. For CHaT, these include:

- Enhancing reliability, lowering costs, and improving safety via a tool that can inform optimal design and mitigation strategies to make the grid more resilient to natural hazard events and disasters.

- Reducing repair frequencies and durations by hardening the grid where hazards are most likely to occur.

- Mitigating loss and damage resulting from hazard events and more efficiently initiating recovery efforts.

With additional validation and use at scale, CHaT also could inform needed earthquake risk mitigation to critical utility assets such as substations.
For GRIP, the benefits include:

- Identifying new climate adaptation strategies to mitigate impact to customers.

- Establishing new planning and hardening strategies focusing on which poles and conductors to harden to minimize future customer impacts.

- Establishing new planning and operational practices to determine where to stage field crews to improve recovery and restoration after a high-wind event in order to reduce outage durations.

- Augmenting existing operational practices for vegetation mitigation planning to reduce outage risks, as well as costs to pay for the impacts of wildfires.

3.5 Technical Lessons Learned and Recommendations

Lessons learned from the project can be applied to projects of similar technical nature and size. These lessons are categorized into three areas:

- **Procurement Management:** Strengthening contract negotiation flexibility with external vendors is needed. Currently, external vendors must be onboarded and provided with computing assets in order to share data while remaining compliant with data management policies.

- **Data and Information Management:** There is a need to establish a data architecture for technical demonstration projects so they can leverage information from enterprise data sources and do not require costly overhead of enterprise architectures.

---

[17] https://www.sce.com/wildfire/wildfire-mitigation-efforts.

- **Technical Capabilities:** The climate models employed in this project demonstrated the use of the latest climate science and data to provide insights about how climate and extreme weather are projected to change for heat, precipitation, flooding, and windstorm events. However, additional analyses are still required to understand in more detail what risks or impacts those projections pose to electric utility assets.

3.6 Technology/Knowledge Transfer Plan

To ensure the transferability and scalability of CHaT, a comprehensive technology transfer plan was established. This plan includes a training program, user manual, and technical support to facilitate the adoption and utilization of the system by the target audiences.

In 2023, SCE held a meeting with several staff members from Argonne National Laboratory – a leading expert in wind simulation – to introduce them to GRIP's capabilities.

In addition, SCE is a member of the Electric Power Research Institute's (EPRI) Climate READi[18] initiative, which is addressing power system climate resilience and adaptation as the occurrence of extreme weather events continues to increase. Initiatives such as this will provide much-needed contributions to knowledge about the maturity of climate-related risk assessment methodologies or models for electric utilities from both industry and academia.

3.7 Procurement

All the items and services intended for the project were successfully procured. The actual costs were within the planned budget, with no significant deviations. However, there were some unanticipated issues that affected procurements, such as long lead times for certain essential items. Overall, the marketplace had mature technologies available to support the project requirements.

3.8 Stakeholder Engagement

The project successfully met stakeholder expectations by improving the grid's vulnerability analysis capabilities. Stakeholders were kept apprised of project performance through regular updates. Project results were communicated through various channels, ensuring transparency and accountability.

SCE stakeholder organizations for the CHaT project, including the work on GRIP:

- Business Resiliency (project sponsor)
- Regulatory Affairs and Planning
- T&D Seismic Analysis, Integrated System Planning
- Strategic Planning
- Grid Edge Innovation
- Wildfire Risk
- Enterprise Risk Management
- Apparatus Engineering
- Network Implementation and Planning
- IT Development
- IT Project Management
- IT Cyber Management
- IT Grid Services
- IT Enterprise Architecture
- EPIC Program Engineering

---

[18] https://www.epri.com/research/sectors/readi.

4 APPENDICES

4.1 Potential Impacts for Climate Hazards

Component	Hazard	Potential Impacts
Electricity Generation: Thermoelectric	High ambient air temperatures	Reduction in plant efficiency and available generation capacity
	High water temperatures	Reduction in plant efficiency and available generation capacity; increased risk of exceeding thermal discharge limits
	Drought and water availability issues	Reduction in available generation capacity; impacts on coal, natural gas, and nuclear fuel supply chains
	Storms, sea level rise, and storm surges	Increased risk of physical damage and disruption to coastal facilities
	Flooding	Increased risk of physical damage and disruption to inland facilities
Electricity Generation: Hydropower	High ambient air temperatures and evaporative losses	Reduction in available generation capacity and changes in operations
	Changes in precipitation and decreasing snowpack	Reduction in available generation capacity and changes in operations
	Flooding	Increased risk of physical damage and changes in operations
Electricity Generation: Wind Energy	Variations in wind patterns	Uncertain impacts on resource potential
Electricity Generation: Solar Energy	High ambient air temperatures	Reduction in potential capacity
	High ambient air temperatures	Derating; decreased capacity; accelerated aging; loss of life
Transmission and Distribution: Transformers	High ambient air temperatures	Reduction in transmission efficiency and available transmission capacity
Transmission and Distribution: Power Lines	Wildfires	Increased risk of physical damage and decreased transmission capacity
	Storm events, including ice storms	Increased risk of physical damage
	High winds	Line damage; failure
Transmission and Distribution: Poles	High ambient air temperatures	Increased electricity demand for cooling; increased adoption of air conditioning
End Use: Demand	Extreme heat events	Reserve margin vulnerability

4.2 Data Sources for Climate Hazard Models

Component	Hazard	Region	# of studies Pub Quantification
T&D	Extreme Heat	U.S.	• LOCA (Locally Constructed Analogs) Statistically Downscaled CMIP5 (Coupled Model Intercomparison Project Phase 5) Projections for North America • Multivariate Adaptive Constructed Analogs (MACA) Downscaled Global Climate Models (GCMs) • Resolution: 1/16º (~5 km): Ratings are relative to the contiguous U.S. and Canada
	Flood	U.S.	• 2019 National Land Cover Database (NLCD) • CADDIES (Cellular Automata Dual-DraInagE Simulation) WCA2D (Weighted Cellular Automata 2D) surface flood model • Federal Emergency Management Agency (FEMA) National Flood Hazard Layer • **LOCA** Statistically Downscaled CMIP5 Projections for North America • National Hurricane Center (NHC) historical hurricane track data • National Oceanic and Atmospheric Administration (NOAA) intensity-duration-frequency curves • NOAA high tide flooding projections • NOAA SLOSH (Sea, Lake and Overland Surges from Hurricanes) model • NOAA tide gauges and sea level rise data • U.S. Department of Agriculture (USDA) Soil Survey Geographic Database (SSURGO) • Woznicki S.A., Baynes J., Panlasigui S., Mehaffey M., Neale A. "Development of a spatially complete floodplain map of the conterminous United States using random forest." *Science of The Total Environment*, Volume 647, pp. 942-953, 10 Jan. 2019, https://www.sciencedirect.com/science/article/pii/S0048969718328481.
	Drought	U.S.	• LOCA Statistically Downscaled CMIP5 Projections for North America Resolution: 1/16º (~5 km). Ratings are relative to the contiguous U.S.

4.3 References

Aivalioti, S. "Electricity Sector Adaptation to Heat Waves." Columbia Law School, Sabin Center for Climate Change Law, New York, NY, January 2015.

Campbell, R.J. "Weather-Related Power Outages and Electric System Resiliency." Congressional Research Service, Library of Congress, Washington, D.C., Aug. 18, 2012.

"Community Resilience Planning Guide for Buildings and Infrastructure Systems: Volume II." National Institute of Standards and Technology, U.S. Department of Commerce, May 2016.

Fernandez, Steven & Allen, Melissa & Omitaomu, Olufemi & Walker, Kimberly. "Application of Hybrid Geo-Spatially Granular Fragility Curves to Improve Power Outage Predictions." *Journal of Geography and Natural Disasters,* 4. 10.4172/2167-0587.1000127, July 2014.

G. Swift, T. S. Molinski and W. Lehn. "A fundamental approach to transformer thermal modeling. I. Theory and equivalent circuit." **IEEE Transactions on Power Delivery**, Vol. 16, No. 2, pp. 171-175, doi: 10.1109/61.915478, April 2001.

Hall, K.L. "Out of Sight, Out of Mind 2012: An Updated Study on the Undergrounding of Overhead Power Lines." Prepared by Hall Energy Consulting, Inc. (Waynesville, N.C.) for Edison Electric Institute (EEI), Washington, D.C., January 2013.

Hazus Technical Manual. National Institute of Building Sciences for the U.S. Federal Emergency Management Agency, Washington, D.C., 1997.

Maher, K. and Peace, J. "Weathering the Next Storm: A Closer Look at Business Resilience." Center for Climate and Energy Solutions, Arlington, VA, September 2015.

"Potential Effects of Climate Change on Electric Utilities." TR-105005 Research Project 2141-11 Final Report. Prepared by ICF RESOURCES INCORPORATED), Fairfax, VA, March 1995.

Scawthorn, Charles & Flores, Paul & Blais, Neil & Seligson, Hope & Tate, Eric & Chang, Stephanie & Mifflin, Edward & Thomas, Will & Murphy, James & Jones, Christopher & Lawrence, Michael. "HAZUS-MH flood loss estimation methodology. II. Damage and loss assessment." *Natural Hazards Review*. 7. 10.1061/(ASCE)1527-6988(2006)7:2(72), May 2006.

"U.S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather." U.S. Department of Energy, July 2013.

Vine, Edward. "Adaptation of California's Electricity Sector to Climate Change." *Climatic Change,* 111. 75-99. 10.1007/s10584-011-0242-2, March 2012.

Wilbanks, T., & Fernandez, S. (Coordinating Lead Authors). "Climate Change and Infrastructure, Urban Systems, and Vulnerabilities: Technical Report for the U.S. Department of Energy in Support of the National Climate Assessment." Washington, D.C.: Island Press, 2013.

Y. Yu, K.R. Moy, W.E. Chapman, P.L. O'Neill and R. Rajagopal. "Assessing climate change vulnerability of microgrid systems." **2016 IEEE Power and Energy Society General Meeting (PESGM)**, Boston, MA, pp. 1-5, doi: 10.1109/PESGM.2016.7742061, 2016.

List of Acronyms

CADDIES	Cellular Automata Dual-DraInagE Simulation
CAIDI	**Customer Average Interruption Duration Index**
CEC	California Energy Commission
CHaT	Comprehensive Hazards Assessment Tool
CMI	Customer Minutes of Interruption
CMIP	Coupled Model Intercomparison Project
CPHC	Central Pacific Hurricane Center
CPUC	California Public Utilities Commission
DOE	(U.S.) Department of Energy
EPIC	Electric Program Investment Charge
EPRI	Electric Power Research Institute
ERF	Earthquake-Rupture Forecast
FEMA	Federal Emergency Management Agency
GCM	Global Climate Models

GCP	Google Cloud Platform
GEM	Global Earthquake Model
GIS	Geographic Information Systems
GMLC	Grid Modernization Lab Consortium (U.S. DOE)
GRIP	Grid Resilience Intelligence Platform
IEEE	Institute of Electrical and Electronics Engineers
IMR	Intensity-Measure Relationship
IPCC	Intergovernmental Panel on Climate Change
IT	Information Technology
km	Kilometer
LOCA	Localized Constructed Analogs
MACA	Multivariate Adaptive Constructed Analogs
MEOW	Maximum Envelope of Water
mph	Miles Per Hour
NHC	National Hurricane Center
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
OpenSHA	Open-Source Seismic Hazard Analysis
PGA	Peak Ground Acceleration
PSHA	Probabilistic Seismic Hazard Analysis
PSPS	Public Safety Power Shutoff
R&D	Research and Development
SAIDI	**System Average Interruption Duration Index**
SCE	Southern California Edison
SCEC	Southern California Earthquake Center
SHA	Seismic Hazard Analysis
SLOSH	Sea, Lake and Overland Surges from Hurricanes
SPOP	Strategy, Planning & Operational Performance
SSURGO	Soil Survey Geographic Database
T&D	Transmission & Distribution
TD&D	Technology Demonstration and Deployment
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WCA2D	Weighted Cellular Automata 2D
WGCEP	Working Group on California Earthquake Probabilities
WMP	Wildfire Mitigation Plan