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California Solar Initiative—Biennial Evaluation Studies for the Single-Family Affordable Solar Homes (SASH) and Multifamily Affordable Solar Housing (MASH) Low-Income Programs

Impact and Cost-Benefit Analysis

Program Years 2011–2013

Prepared for:
California Public Utilities Commission

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List of Acronyms

AB	Assembly Bill
AC	Alternating Current
AMI	Area Median Income
CAISO	California Independent System Operator
CARE	California Alternative Rates for Energy
CF	Capacity Factor
CO_2	Carbon Dioxide
CSE	California Center for Sustainable Energy
CEC	California Energy Commission
CERR	Clerical Error Realization Rate
CIMIS	California Irrigation Management Information System
CO	Carbon Monoxide
CPUC	California Public Utilities Commission
CSI	California Solar Initiative
DC	Direct Current
DEER	Database of Energy-Efficient Resources
DF	Design Factor
DFVR	Design Factor Verification Rate
DOE	U.S. Department of Energy
E3	Energy + Environmental Economics
EIA	U.S. Energy Information Administration
EPA	U.S. Environmental Protection Agency
EPBB	Expected Performance-Based Buydown
ESA	Energy Savings Assistance Program
FIWS	Field Inspection Worksheet
GHG	Greenhouse Gas
HUD	U.S. Department of Housing and Urban Development
IOU	Investor-Owned Utility
kW	Kilowatt
kW-AC (CEC)	Kilowatts, Alternating Current (California Energy Commission-AC Rating)
kW-AC (meter)	Kilowatts, Alternating Current (As Measured at the Utility Meter)
kW-DC (PTC)	Kilowatts, Direct Current (Rated at PVUSA Testing Conditions)
kW-DC (STC)	Kilowatts, Direct Current (Rated at Standard Testing Conditions)
kWh	Kilowatt-Hour
LIPPT	Low-Income Public Purpose Test
M&E	Measurement and Evaluation
MACRS	Modified Accelerated Cost Recovery System
MASH	Multifamily Affordable Solar Housing
MW	Megawatt
MWh	Megawatt-Hour

NEB	Non-Energy Benefit
NEM	Net Energy Metering
NPV	Net Present Value
NREL	National Renewable Energy Laboratory
O&M	Operations and Maintenance
PA	Program Administrator
PAC	Program Administrator Cost Test
PCT	Participant Cost Test
PDF	Portable Document Format
PG&E	Pacific Gas & Electric
PPA	Power Purchase Agreement
PST	Pacific Standard Time
PTC	PVUSA Test Conditions
PV	Photovoltaic
QC	Quality Control
RECS	Residential Energy Consumption Survey
RIM	Ratepayer Impact Measure Test
SASH	Single-Family Affordable Solar Housing
SAM	System Advisor Model
SB	Senate Bill
SCE	Southern California Edison
SCT	Societal Cost Test
SDG&E	San Diego Gas & Electric
SGIP	Self-Generation Incentive Program
SPM	Standard Practice Manual (California)
SPP	Sub-Contractor Partnership Program
STC	Standard Testing Condition
TMY	Typical Meteorological Year
TPO	Third-Party Ownership
TRC	Total Resource Cost
VNM	Virtual Net Energy Metering
W	Watt

Executive Summary

This Impact and Cost-Benefit Analysis Report is one of three reports that the Navigant team is completing as part of the Single-Family Affordable Solar Housing (SASH) and Multifamily Affordable Solar Housing (MASH) evaluation effort:

- Market and Program Administrator Assessment
- Impact and Cost-Benefit Analysis
- Summary of Program Design Recommendations

This report focuses on quantifying the annual benefits and costs of the SASH and MASH programs using California Public Utilities Commission (CPUC or Commission)-approved methodologies. Notably, under Assembly Bill (AB) 217,[1] the Commission must design the SASH and MASH programs to maximize the overall benefit to ratepayers. This study should help inform the efforts of Commission staff and the Program Administrators (PAs) tasked with that responsibility.

BACKGROUND

The California Solar Initiative (CSI) provides solar incentives to customers of the investor-owned utilities (IOUs) in California to increase the adoption of solar energy. The CSI program set aside 10 percent of CSI program funds ($216 million) for residential low-income single-family and multifamily solar projects through the SASH and MASH programs through the end of 2016.[2] The CPUC requires a biennial assessment of SASH and MASH program performance.

The SASH program, which provides financial assistance for the installation of solar photovoltaic (PV) generating systems on qualifying affordable single-family homes, began offering incentives in May 2009. GRID Alternatives (GRID), an Oakland-based non-profit organization, administers the SASH program.[3]

In February 2009, the MASH program began providing financial assistance for the installation of solar PV on affordable multifamily housing. Three PAs administer the MASH program: Pacific Gas & Electric Company (PG&E), Southern California Edison (SCE), and the Center for Sustainable Energy (CSE) in San Diego Gas & Electric (SDG&E) territory.

In 2013, California legislature passed AB 217, authorizing an additional $108 million in funding for the SASH and MASH programs and extending the programs through the end of 2021, or until the programs

[1] The full text of AB 217, Chapter 609 may be found here: http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB217.
[2] According to the CSI Program Handbook, the SASH and MASH programs are scheduled to end December 31, 2015. All SASH and MASH installations must be completed by September 30, 2016 to receive the program incentive payment (http://www.gosolarcalifornia.ca.gov/documents/CSI_HANDBOOK.PDF).
[3] For more information on GRID Alternatives, see http://www.gridalternatives.org/.

exhaust the funds—whichever occurs sooner.[4] Under AB 217, the SASH and MASH programs have a combined capacity target of 50 MW of solar PV for low-income residential housing. Other requirements include: the programs must maximize the overall benefit to ratepayers; participants who receive monetary incentives be enrolled in the Energy Savings Assistance (ESA) program, if eligible; and the programs provide job training and employment opportunities in the solar energy and energy efficiency sectors.

On January 29, 2015, the CPUC issued the Decision Extending the Multifamily Affordable Solar Housing and Single Family Affordable Solar Housing Programs within the CSI (D. 15-01-027).[5] The decision allocates $54 million in funding for each program and sets a target of 15 MW for SASH and 35 MW for MASH. The decision also includes guidance on administration for each program.

EVALUATION APPROACH

The Navigant project team collected primary data through the completion of 10 desk reviews and five field visits for the SASH program and 10 desk reviews and five field visits for the MASH program. In addition, the team used a variety of secondary sources to complete the impacts and cost-benefit analyses contained in this report. Navigant also included questions from the in-depth interviews completed as part of the Market and Program Administrator Assessment and secondary research to inform a high-level qualitative and quantitative assessment of non-energy benefits (NEBs) of SASH and MASH program elements.

SASH PROGRAM FINDINGS

This section highlights the key findings for the SASH program. The findings are grouped by desk review and field verification, impact analysis, and cost-benefit analysis.

- **Desk Review and Field Verification**
    - A field verification of the SASH projects[6] showed that systems are generally operating as expected, with some minor issues in data management and tracking. These issues had very little effect on the reported output.
- **Impact Analysis**
    - The SASH program incentivized the installation of 3,164 PV projects between 2011 and 2013, providing 9,731 kW-AC (California Energy Commission, or CEC)[7] of

[4] The full text of AB No. 217, Chapter 609 is available at: http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB217

[5] http://www.cpuc.ca.gov/NR/rdonlyres/D6EBBFCE-3C9D-4631-9F4E-94A58F765DF5/0/145938475.pdf

[6] Throughout this report, a SASH project refers to a specific SASH application number.

[7] The Salesforce database for the SASH program reports installed capacity as a CEC-AC rating. Throughout this report kW-AC (CEC) refers to the CEC-AC rating, while kW-AC (meter) refers to kilowatts AC as measured or modeled at the utility meter.

interconnected capacity. The average project system size was 3.1 kW-AC (CEC).[8] The rate of new system installations has followed a steadily increasing trend.

- The 3,164 SASH projects generated approximately 23,824 MWh of electricity from 2011–2013, with an expected total annual production of 17,536 MWh in a typical year thereafter.
- The weighted average annual capacity factor[9] for SASH projects in 2011–2013 ranged between 17 percent and 18 percent.
- During California Independent System Operator (CAISO) peak demand, Navigant models estimated that the SASH projects reduced the peak demand by about 587 kW-AC (meter) in 2011, about 2,919 kW-AC (meter) in 2012, and about 4,265 kW-AC (meter) in 2013.
- SASH participants saw a typical first-year bill reduction of approximately $756 in 2011–2013. Participants on California Alternative Rates for Energy (CARE) rates averaged about one-third lower bill reductions than participants on non-CARE rates primarily due to the CARE customers' lower cost of energy.

- **Cost-Benefit Analysis**
  - The SASH program is cost-effective from the participant perspective, but it is not cost-effective from the societal, PA, ratepayer, or total resource perspectives.
  - The inclusion of NEBs increased the SASH cost-benefit ratios by 29 percent for the Total Resource Cost (TRC), 22 percent for the Societal Cost Test (SCT), 28 percent for the Program Administrator Cost Test (PAC) and Ratepayer Impact Measure Test (RIM), and four percent for the Participant Cost Test (PCT).
  - On a levelized $/participant-year basis, SASH participants received about four percent of the total SASH NEBs, while the IOUs received 96 percent.
  - Navigant analysis showed the avoided rate subsidy for CARE payments makes up a large portion of the NEBs for SASH projects.
  - SASH homeowners and other market actors agree that reducing homeowner utility bills and benefits to the environment were the two most important SASH program benefits, with over 60 percent of respondents choosing one of those two as their top benefit.

MASH PROGRAM FINDINGS

This section highlights the key findings for the MASH program. The findings are grouped by desk review and field verification, impact analysis, and cost-benefit analysis.

[8] An interconnected project is a PV system that has been installed, inspected by a third party (if applicable), tied to the utility grid, and is expected to be producing power. A project that does not meet all of the requirements of an interconnected project is considered to be in process.

[9] CF is a ratio of the actual output of a system during a specified timeframe to the theoretical rated capacity of that system during the same timeframe.

- **Desk Review and Field Verification**
    - A field verification of the MASH systems showed that systems are generally operating as expected, with some minor issues in data management and tracking. These issues had very little effect on the reported output.
- **Impact Analysis**
    - The MASH program incentivized the installation of 273 PV projects[10] between 2011 and 2013, providing 18,400 kW-DC (PTC)[11] of interconnected capacity. The average project size was 67.4 kW-DC (PTC). The rate of new system installations increased in 2011–2012 and tapered significantly in 2013.
    - The 273 projects generated approximately 60,191 MWh of electricity from 2011–2013, with expected total annual production of 35,626 MWh in a typical year thereafter.
    - The weighted average annual capacity factor for MASH systems in 2011–2013 ranged between 22 percent and 23 percent.
    - During CAISO peak demand, Navigant models estimated that the MASH systems reduced the peak demand by about 2,272 kW-AC (meter) in 2011, about 7,641 kW-AC (meter) in 2012, and about 9,594 kW-AC (meter) in 2013.
    - MASH tenants (specifically only those receiving direct benefits from the program in the form of reduced electricity bills) saw a typical first-year annual bill reduction of approximately $484 in 2011–2013. Tenants on CARE rates averaged savings about 30 percent lower than those on non-CARE rates. Average tenant allocation was 1.5 kW-DC (PTC).
    - MASH building owners averaged first-year bill savings of $404/kW-DC (STC) capacity in 2011–2013.
- **Cost-Benefit Analysis**
    - The MASH program is cost-effective from the participant perspective but not from the societal, PA, ratepayer, or total resource perspectives.
    - The inclusion of NEBs increased the MASH cost-benefit ratios by 15 percent for the TRC, 11 percent for the SCT, 13 percent for the PAC and RIM, and a negligible amount for the PCT.
    - Despite declining installed system cost trends in the U.S. PV market, MASH system installation costs did not decrease over time. For comparison, SASH system installed

[10] Throughout this report, the term "project" for the MASH program refers to all PV arrays incentivized under a unique MASH application number. Individual applications may include multiple buildings with distinct physical addresses.

[11] The PowerClerk database for the MASH program reports installed capacity in both the CEC PTC and STC (nameplate) ratings. Throughout this report, kW-DC (PTC) refers to capacity rating at PVUSA Test Conditions, while kW-DC refers to capacity rating at Standard Testing Conditions.

costs decreased every year from 2011–2013. Determining the reason for this cost trend was not within the scope of this evaluation.

- While there could be some NEBs applicable to building owners, Navigant's analysis focused on NEBs for tenants. Therefore, NEBs may have a smaller impact on MASH cost-effectiveness than SASH cost-effectiveness because the MASH NEBs are applicable to a smaller portion of participants (tenants only and not owners).[12]
- On a levelized $/participant-year basis, MASH tenants received about eight percent of the total MASH NEBs, while the IOUs received 92 percent.
- Navigant analysis showed the avoided rate subsidy for CARE payments makes up a large portion of the NEBs for MASH projects.
- MASH tenants and other market actors agree that reducing utility bills and benefits to the environment were the two most important MASH program benefits.

RECOMMENDATIONS

The Navigant team identified the following recommendations:

- **Conduct a detailed, bottom-up analysis of the NEBs of the SASH and MASH programs.** One of the goals of the extended SASH and MASH programs is to maximize benefits to ratepayers.[13] The current NEB analysis is limited in scope and was adapted from a model that is not specific to PV solar programs; thus, the results are illustrative rather than comprehensive. A quantitative, in-depth understanding of NEBs of the SASH and MASH programs would allow the CPUC to properly assess and attribute relevant benefits to the ratepayers, thus enabling better evaluation of the extended programs' progress toward meeting their stated goals.

  The analysis would first include a review of the literature and in-depth interviews with subject matter experts to confirm the categories of NEBs that are associated with low-income distributed generation programs. The team would then develop a methodology and modeling framework for organizing and estimating NEBs. Finally, the team would conduct primary and secondary research to derive IOU-specific, program-induced benefits for each of the NEBs categories. It is envisioned that the research would include a data request to obtain utility and program-specific information from each of the IOUs and a survey of SASH and MASH participants.

- **Implement a long-term strategy for supporting SASH inverters after the current 10-year warranty period [Applicable to SASH only].** GRID Alternatives currently meets the program requirements for a CSI standard 10-year warranty. However, because the PV modules will outlast the inverters and SASH customers may not have the means to replace them, it is important to plan for the eventuality of a certain percentage of inverter replacements each year. The stated goal of the SASH program is to decrease electricity usage by solar installation and to reduce energy bills without

[12] The NEB analysis focused on benefits for VNM tenants rather than on benefits for all tenants.
[13] AB 217 states this goal. The full text of AB 217, Chapter 609 may be found here: http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB217.

increasing monthly expenses. Even though GRID Alternatives currently provides training to SASH participants on how to save for eventual operations and maintenance (O&M) costs,[14] it is likely that many SASH customers will have difficulty paying for replacement inverters (in the event of inverter failure)—especially with higher monthly energy costs due to the failed PV system. By revising program goals to include a long-term strategy for supporting the replacement of SASH inverters after 10 years, the SASH program would be able to maintain the reduced electricity bills for customers over a longer time horizon.

- **The CPUC should work with the PAs to ensure consistent and accurate installation and field inspection procedures.** This recommendation stems from two evaluation findings—the first from the field verification visits and the second from the desk review. Each finding and a related recommendation appears below.
    - **A high number of azimuth angle discrepancies uncovered in the field are greater than 10 degrees from the tracking database-reported values.** Out of the 14 MASH arrays verified via site visits, six had azimuth discrepancies greater than five degrees, the threshold requiring re-calculation of design factor. At the SASH sites, five out of eight arrays had discrepancies greater than five degrees. Many of the discrepancies for both programs were greater than 10 degrees, signifying a need for further training for inspectors and/or installers, particularly around magnetic declination and proper calculation of true array azimuth. While azimuth discrepancies do not have a large impact on design factor,[15] record accuracy and quality control are still important. According to AB 217, one of the goals of the SASH and MASH programs is to provide job training and employment opportunities in the solar energy and energy efficiency sectors of the economy. Adding in-service training for inspectors and lead installers around properly determining system characteristics would improve their skillsets and professionalism. The CPUC should consider working with the PAs to provide training for lead installers and inspectors around consistent PV characteristic reporting.
    - **Inspection policies should be consistent across PAs [Applicable to MASH only].** Currently, third-party inspectors at PG&E sites verify only a subset of arrays at sites with more than about 30 arrays. The inspectors for SCE and CSE typically verify all arrays onsite. Navigant recommends either verifying all arrays or at least verifying array capacity. The justification for this recommendation comes from a program goal stated in the MASH handbook:

        > *"Program Administrators will conduct a system inspection visit for each Incentive Form submitted to verify that the project is installed as represented in the application. . ."*

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[14] Navigant did not estimate non-inverter O&M costs as a part of the cost-benefit analysis.

[15] The design factor describes the relative efficacy of an installed PV system against an ideal system. PAs use design factor in part to determine applicant eligibility for incentives.

Developing a consistent policy for how to treat inspections at sites with a large number of arrays will serve MASH program goals by improving the inspection quality and making it consistent across all PAs. The most robust policy for third-party inspections would be to require 100 percent inspection of all arrays at MASH sites. At minimum, inspectors should verify the total quantity and nameplate rating of those arrays that are not included in the full verification, if sampling is required for budgetary reasons.

1 Introduction

This Impact and Cost-Benefit Analysis Report is one of three reports that the Navigant team is completing as part of the Single-Family Affordable Solar Housing (SASH) and Multifamily Affordable Solar Housing (MASH) evaluation effort:

- Market and Program Administrator Assessment
- Impact and Cost-Benefit Analysis
- Summary of Program Design Recommendations

This report focuses on quantifying the annual benefits and costs of the SASH and MASH programs using California Public Utilities Commission (CPUC or Commission)-approved methodologies. Notably, under Assembly Bill (AB) 217,[16] the Commission must design the SASH and MASH programs to maximize the overall benefit to ratepayers. This study should help inform the efforts of Commission staff and the Program Administrators (PAs) tasked with that responsibility.

This section presents context for this evaluation report, beginning with an overview of the evaluated programs and their status through 2013, followed by a summary of other relevant research and a discussion of this research effort's objectives and research questions. In addition, the section includes the structure for the remainder of this report, as follows:

- Section 1.1—Program Overview
- Section 1.2—Other SASH and MASH Evaluation Reports
- Section 1.3—Research Objectives
- Section 1.4—Report Organization

1.1 PROGRAM OVERVIEW

This section provides background information on the SASH program and MASH program. It also provides a discussion of recent changes to the program, as required by AB 217. This section is organized as follows:

- Section 1.1.1—Background of the California Solar Initiative and SASH and MASH Programs
- Section 1.1.2—AB 217 and New Program Rules

[16] The full text of AB 217, Chapter 609 may be found here: http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB217.

1.1.1 Background of the California Solar Initiative and SASH and MASH Programs

The California Solar Initiative (CSI) is one component of the Go Solar California! campaign.[17] Overseen by the California Public Utilities Commission (CPUC or Commission), the CSI has a goal of installing 1,940 MW of distributed solar capacity in the investor-owned utility (IOU) service territories by the end of 2016. The program was established by California Senate Bill (SB) 1 in August 2006 and was initiated in January 2007; it has a $2.167 billion budget over its 10-year period.[18]

SB 1 and AB 2723 (Pavley, 2006) required the CPUC to set aside at least 10 percent of CSI funds to be used for installation of solar photovoltaic (PV) systems on low-income residential housing. Pursuant to this direction, in 2007, the CPUC authorized the SASH incentive program with $108 million in funding for the installation of solar PV systems on single-family homes, and in 2008, authorized the MASH incentive program with $108 million in funding for the installation of solar PV systems on multifamily housing. The CPUC did not adopt explicit capacity goals for either program at that time.

SASH PROGRAM GOALS

- Decrease electricity usage by solar installation and reduce energy bills without increasing monthly expenses
- Provide full and partial incentives for solar systems for low-income participants
- Offer the power of solar and energy efficiency to homeowners
- Decrease the expense of solar ownership with a higher incentive than the CSI General Market Program
- Develop energy solutions that are environmentally and economically sustainable

Source: www.cpuc.ca.gov/PUC/energy/Solar/sash.htm

The SASH program offers fully or highly subsidized solar systems to qualified low-income homeowners. To qualify for a fully subsidized system, homeowners have to meet the legal definition of low-income residential housing in Public Utilities Code Section 2852. Eligibility is limited to owner-occupied households that receive electric service from the IOUs and whose household income is at or below 80 percent of the area median income (AMI) based on the most recent available income tax return. The residence must also meet an affordable housing requirement by being California Public Utilities Code Section 2852-compliant. The CPUC selected GRID Alternatives (GRID), an Oakland-based non-profit organization, via a competitive solicitation to administer the SASH program.

From program inception through 2013, 3,505 solar PV systems had been installed for a total installed capacity of 10.589 MW in the SASH program. According to its database, GRID Alternatives allocated $64.87 million in SASH incentives from program inception to the end of 2013. From 2011–2013, the SASH program installed 3,164 solar PV systems, comprising 9.731 MW of installed capacity. At the end of 2013,

[17] The Go Solar California! campaign is a joint effort of the California Energy Commission (CEC) and the CPUC to encourage Californians to install 3,000 MW of solar energy systems on homes and businesses by the end of 2016. The program also has a goal to install 585 million therms of gas-displacing solar hot water systems by the end of 2017. (http://www.gosolarcalifornia.ca.gov/about/index.php).

[18] SB 1 (Murray, Chapter 132, Statutes of 2006) and Public Resources Code (PRC) 25780.

262 additional projects were reserved and awaiting installation or interconnection[19] and another 682 applications had been submitted and were under review.[20]

The MASH PAs are Pacific Gas & Electric Company (PG&E), Southern California Edison (SCE), and the Center for Sustainable Energy (CSE) in San Diego Gas & Electric (SDG&E) territory. Prior to AB 217, which reauthorized funding for the MASH program and established new program rules,[21] the MASH program provided two types of incentives: Track 1A incentives for PV systems offsetting common area load and Track 1B incentives for PV systems offsetting tenant load. The program initially provided a Track 2 incentive for projects that proposed innovative approaches to providing tenant benefits, but the CPUC subsequently closed that portion of the program due to poor participation.[22] To qualify for MASH Track 1A or Track 1B incentives, a property had to meet the definition of low-income residential housing per Public Utilities Code Section 2852 and have an occupancy permit.

As of June 9, 2009, the CPUC approved a virtual net energy metering (VNM) tariff for the IOUs to facilitate the provision of solar PV with tenant offsets. The VNM tariff directly allocates solar benefits to low-income tenants without requiring the system to physically connect to each tenant meter. VNM allows the owner to install one system and designate a set percentage of the solar output to the common area and to each tenant based on the relative tenant unit sizes. On the other hand, MASH projects that only serve common area load use net energy metering (NEM) tariffs that provide credit to properties for the excess generation that the PV systems export to the electric grid during times when it is not serving onsite load.[23]

MASH PROGRAM GOALS

- Decrease electricity use and costs without increasing monthly household expenses for affordable housing building occupants
- Stimulate the adoption of solar power in the affordable housing sector
- Improve energy utilization and overall quality of affordable housing through the application of solar and energy efficiency technologies
- Increase awareness and appreciation of the benefits of solar among affordable housing occupants and developers

Source: www.cpuc.ca.gov/PUC/energy/Solar/mash.htm

By the end of 2013, the MASH program had installed 321 PV systems for a total installed capacity of 20.7 MW from program inception through 2013. According to PowerClerk data, the MASH program allocated $70.96 million in incentives from program inception through the end of 2013. From 2011–2013, the MASH program installed 273 solar PV systems, comprising 18.4 MW of installed capacity. At the end

[19] Categorized as Approved-Construction in the SASH Salesforce database.

[20] Categorized as Approved-Outreach in the SASH Salesforce database.

[21] AB 217 is discussed in more detail in Section 1.1.2.

[22] For more information, see the full published decision at: http://docs.cpuc.ca.gov/PUBLISHED/FINAL_DECISION/139683.htm. The Track 2 incentives decision is described in Section 7.3.

[23] The CPUC NEM website contains more information on NEM: http://www.cpuc.ca.gov/PUC/energy/DistGen/netmetering.htm.

of 2013, 55 additional projects were reserved and awaiting installation,[24] and another 302 applications were on the wait list.

1.1.2 AB 217 and New Program Rules

AB 217 (Bradford, 2013) extended the SASH and MASH programs, authorizing an additional $108 million in funding and extending the programs through the end of 2021, or until the funds are exhausted—whichever occurs sooner.[25]

Under AB 217, the SASH and MASH programs have a combined capacity target of 50 MW of solar PV for low-income residential housing. Other requirements include: the program must be designed to maximize the overall benefit to ratepayers; participants who receive monetary incentives be enrolled in the Energy Savings Assistance (ESA) Program, if eligible; and the program must provide job training and employment opportunities in the solar energy and energy efficiency sectors.

On January 29, 2015, the CPUC issued the Decision Extending the Multifamily Affordable Solar Housing and Single Family Affordable Solar Housing Programs within the CSI (D. 15-01-027).[26] The decision allocates $54 million in funding for each program and sets a capacity target of 15 MW for SASH and 35 MW for MASH. The decision also includes guidance and program administration requirements including but not limited to the following:

- Enrollment in the ESA program for eligible MASH tenants
- Job training and employment opportunities on all solar PV systems installed
- GRID Alternatives as the PA for SASH and PG&E, SCE, and CSE as the PAs for MASH
- A confidential Data Annex to be submitted with the semi-annual SASH and MASH program reports that includes the number of job trainees, job type, and hours worked
- Request to GRID Alternatives to file a Tier 3 advice letter that proposes a third-party ownership (TPO) model for the SASH program

With the recent implementation of AB 217, this study may help inform the efforts of Commission staff and PAs tasked with implementing the new program requirements. Figure 1-1 presents a regulatory timeline for the SASH and MASH programs from 2006 through 2017.

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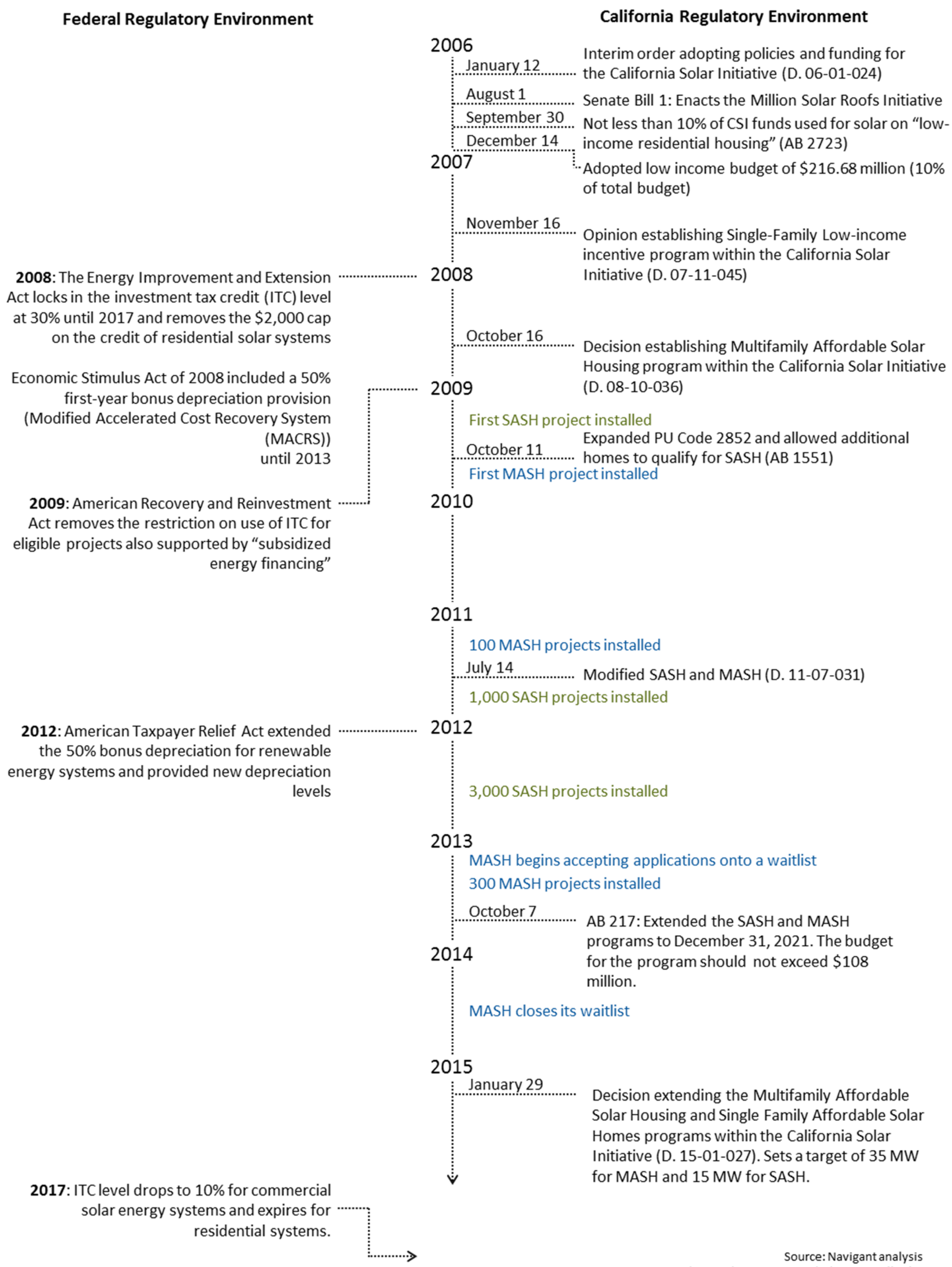
[24] Categorized as Confirmed Reservation or Reservation Reserved in the PowerClerk database.
[25] The full text of AB 217, Chapter 609 may be found here: http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB217.
[26] http://www.cpuc.ca.gov/NR/rdonlyres/D6EBBFCE-3C9D-4631-9F4E-94A58F765DF5/0/145938475.pdf

Figure 1-1. Regulatory Timeline



Source: Navigant analysis
Note: This graphic is not intended to cover all solar activity during the timeframe.

1.2 OTHER SASH AND MASH EVALUATION REPORTS

This study builds upon previous SASH and MASH evaluation studies conducted by Navigant in 2011.[27] The 2011 reports include:

- CSI SASH and MASH Program Administrator Performance Assessment Report[28]
- CSI SASH and MASH Market Assessment Report[29]
- CSI SASH Biennial Report[30]
- CSI MASH Biennial Report[31]
- CSI SASH and MASH Impacts and Cost-Benefit Report[32]

1.3 RESEARCH OBJECTIVES

The primary goal of this study is to quantify the annual costs and benefits of the SASH and MASH programs using Commission-approved methodologies as outlined in the California Standard Practice Manual (SPM).[33] Notably, under AB 217,[34] the Commission must design the SASH and MASH programs to maximize the overall benefit to ratepayers. This study will help inform the efforts of Commission staff and PAs tasked with this responsibility. However, it is worth noting that the California SPM tests have limitations for evaluating low-income programs.[35] Thus, in this evaluation Navigant worked closely with the CPUC's Energy Division to develop a method of inclusion for non-energy benefits (NEBs) in an effort to recognize the benefits that these low-income programs create that are not captured in the existing SPM framework. Because there is not an established methodology for low-income distributed generation programs, Navigant adapted the CPUC's Low-Income Public Purpose Test (LIPPT), which

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[27] The full reports are available on the CPUC website at: http://www.cpuc.ca.gov/PUC/energy/Solar/CSI+sash_mash+li+evaluation.htm.

[28] Available at: http://www.cpuc.ca.gov/NR/rdonlyres/3A60572D-725B-434E-A525-077428DE4E5D/0/CSIMASHandSASHPAAssessmentReport_2011.pdf

[29] Available at: http://www.cpuc.ca.gov/NR/rdonlyres/EB601615-61B3-43B2-B034-EEC95AF46708/0/CSISASHandMASHMarketAssessmentReport.pdf

[30] Available at: http://www.cpuc.ca.gov/NR/rdonlyres/FEDCFF17-1FCC-4E42-BE6D-AD8EC45838BD/0/CSISASHBiennialReport.pdf

[31] Available at: http://www.cpuc.ca.gov/NR/rdonlyres/BA047AB8-7EC3-4991-8DB5-FCE46CDDF5D1/0/CSIMASHBiennialReport.pdf

[32] Available at: http://www.cpuc.ca.gov/NR/rdonlyres/13AAEDF8-BB7D-4FBD-AC05-3FC2B9CBF746/0/CSISASH_MASHImpact_and_Cost_Benefit_Report.pdf

[33] http://www.cpuc.ca.gov/NR/rdonlyres/004ABF9D-027C-4BE1-9AE1-CE56ADF8DADC/0/CPUC_STANDARD_PRACTICE_MANUAL.pdf

[34] The full text of AB 217, Chapter 609 may be found here: http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB217.

[35] California Public Utilities Commission. October 2001. "California Standard Practice Manual: Economic Analysis of Demand-Side Programs and Projects." SPM Section 4.2 (6), *"Non-energy benefits for low income program: The low income programs are social programs which have a separate list of benefits included in what is known as the 'low income public purpose test'. This test and the specific benefits associated with this test are outside the scope of this manual."*

evaluates NEBs for low-income energy efficiency programs, and included a qualitative assessment of NEBs.

Table 1-1 outlines the research objectives, divided into three primary subtasks: desk review and field verification, impact analysis, and cost-benefit analysis. The current study focuses on impacts, costs, and benefits attributable to the SASH and MASH programs during program years 2011–2013. Per the evaluation solicitation, the cost-benefit analysis included an assessment of the NEBs of SASH and MASH program elements.[36] The previous evaluation cycle and report covered program years 2009 and 2010. Unless otherwise stated, findings included herein apply only to SASH and MASH systems installed and incentivized during 2011–2013.

Table 1-1. Research Objectives

Impact and Cost-Benefit Analysis
Desk Review and Field Verification • Verify installed capacity and system characteristics for model input
Impact Analysis • Assess bill impacts for participating customers • Understand degree to which tenants served by MASH projects receive benefits from the program
Cost-Benefit Analysis • Calculate benefits and costs according to conventional cost-effectiveness tests[37] • Assess NEBs of SASH and MASH program elements and calculate modified cost-effectiveness tests

Source: Navigant Consulting, Inc.

1.4 REPORT ORGANIZATION

The remainder of this report is organized as follows:

- Section 2 describes the evaluation approach used for the desk review and field verification, impact, and cost-benefit analysis
- Section 3 presents the findings for the SASH program
- Section 4 presents the findings for the MASH program
- Section 5 summarizes program-related recommendations for both SASH and MASH programs
- Appendix A contains a list of evaluation-specific data quality recommendations
- Appendix B details the field data collection protocol
- Appendix C provides additional details on approach and assumptions
- Appendix D contains supplemental results tables

[36] Solicitation 13PS5020. State of California. "CSI SASH and MASH Low-Income Programs." December 10, 2013.
[37] Calculated tests include TRC, SCT, PAC, PCT, and RIM. Definitions of these tests appear in Section 2.3.1.

2 Evaluation Approach

The current study focuses on the impacts, costs, and benefits attributable to the SASH and MASH programs during program years 2011–2013. The previous evaluation cycle and report covered program years 2009 and 2010. Unless otherwise stated, Navigant applied the methodologies described herein only to SASH and MASH systems installed and incentivized during 2011–2013.

Navigant conducted the SASH and MASH analyses in parallel. Due to similarities in approach for evaluating the SASH and MASH programs, the below methodologies apply to both programs, with differences explicitly noted in the report. This section is organized as follows:

- Section 2.1—Desk Review and Field Verification Methodology
- Section 2.2—Impact Analysis Methodology
- Section 2.3—Cost-Benefit Analysis Methodology

2.1 DESK REVIEW AND FIELD VERIFICATION METHODOLOGY

Navigant inspected SASH and MASH projects by visiting the project site and verifying the system characteristics. The team completed this desk review and field verification of SASH and MASH projects to meet the following objective:

- Verify installed capacity and system characteristics for model input, which consisted of the following sub-objectives:
    - Identify how systems are operating relative to expectations
    - Verify system installation characteristics used in calculating the Expected Performance-Based Buydown (EPBB) Design Factor (DF) [38]

Field verification allows the team to identify how systems are operating relative to expectations. During each site visit, the field technician calculates expected system output based on measured solar radiation and installed PV capacity and compares that value to the instantaneous output reading from the inverter. This procedure would identify the presence of major issues causing lower than expected PV output. For more detail on the onsite measurement and calculations see Appendix B.

In addition, field verification aimed to verify system installation characteristics used in calculating the EPBB DF. The DF describes the relative efficacy of an installed PV system against an ideal system. PAs

[38] The DF is the product of the Design Correction (the ratio of summer output of the proposed system and the summer output of the optimal system at the proposed location) and the Geographic Correction (the ratio of the annual output of the summer optimal south-facing system at the proposed location and the annual output of the summer optimal south facing system at the reference location). For additional information, see http://www.csi-epbb.com/CSI-EPBBCalculatorUserGuide.pdf.

use DF in part to determine applicant eligibility for incentives. For SASH, PV systems must meet a minimum DF of 85 percent to receive incentives. For MASH, the PA determines a system's incentive level by multiplying the incentive rate by the system DF.[39] Design Factor Verification Rate (DFVR), calculated based on the results of the field verification, is a ratio comparing Navigant-verified DF to PA-reported DF and indicates the accuracy of the DFs reported in the tracking database.

In addition to field verification, Navigant also completed a desk review of PV system characteristics recorded in the program tracking database and compared the characteristics to those in the program application documentation. This allowed Navigant to identify any clerical errors or systematic discrepancies.

The remainder of this section details the methodologies used for the desk review and field verification and is organized as follows:

- Section 2.1.1—Sampling Approach
- Section 2.1.2— Segmentation
- Section 2.1.3—Recruiting
- Section 2.1.4—Data Collection Field Guide
- Section 2.1.5—Data Management and Flow
- Section 2.1.6—Site Visits

2.1.1 Sampling Approach

Navigant's sample design for the field verification and desk review resulted in a sample size of 10 field visits (five field visits for SASH and five field visits for MASH) and 20 desk reviews (10 desk reviews for SASH and 10 desk reviews for MASH) (see Table 2-1). Navigant designed the sample to meet a 90/30 confidence and relative precision estimate of the DFVR. The team used the results from the 2009–2010 evaluation to inform the sample design.

Table 2-1. SASH and MASH Field Visit and Desk Review Sample Sizes

Program	Field Visit Sample Size	Desk Review Sample Size
SASH	5	10
MASH	5	10

Source: Navigant Consulting, Inc.

The goal of the field verification and desk review sampling for the SASH and MASH programs was to obtain a 90/30 confidence and relative precision estimate of the DFVR. During the scoping process that occurred at the beginning of this evaluation, the Navigant and CPUC teams agreed that 90/30 confidence

[39] For details on the SASH and MASH implementation and application procedures, see the CSI Handbook: http://www.gosolarcalifornia.ca.gov/documents/CSI_HANDBOOK.PDF (Accessed August 19, 2015).

and relative precision is an acceptable level of uncertainty for the current evaluation. The team based this decision on the *California Energy Efficiency Evaluation Protocols*[40] and the *California Evaluation Framework.*[41] The *Protocols* are not necessarily binding on the CPUC because this is not an energy efficiency program. However, it is the most relevant guidance document. The 90/30 confidence and relative precision target aligns with a basic level of rigor in the *Protocols* document and the budget for this project.

The team agreed that the basic level of rigor for the field verification and desk review was appropriate based on the following criteria outlined in the *California Evaluation Framework:*

- **Amount of savings:** The SASH and MASH programs have a combined 90 MW–100 MW installed capacity estimate (~43 MW to date plus the 50 MW expected under AB 217). This installed capacity is small relative to other energy efficiency and distributed generation savings in California.
- **Growing or shrinking:** The team expects the programs to grow and then terminate after 2021.
- **Uncertainty and risk:** The programs' savings, based on the previous evaluation, are relatively certain and do not pose a significant risk to the overall portfolio of energy efficiency and distributed generation programs.
- **Time since last evaluation:** The team completed the last evaluation in 2011.

The team then used the data from the previous evaluation to complete the sample design. The data in the 2009–2010 SASH/MASH Impact Evaluation report indicates a mean SASH DFVR of 100 percent with standard error on the mean (sample standard deviation) of 4.1 percent using the 83 observations with good wiring.[42] Navigant used these results to estimate the sample size necessary to generate the target confidence and relative precision of 90/30 in a new sample as shown below. This approach is valid because the new sample is drawn from a similar population.[43]

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[40] The TecMarket Works Team. "California Energy Efficiency Evaluation Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals." Prepared for the California Public Utilities Commission. April 2006. Available at http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/EM+and+V/.

[41] The TecMarket Works Team. "The California Evaluation Framework." Prepared for the California Public Utilities Commission. June 2004. Available at http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/EM+and+V/.

[42] Navigant excluded two sites from the sample that had panel wiring-related issues, which caused severely depleted PV output.

[43] Navigant assumed variation in DFVR to be the same between SASH and MASH in order to calculate the new MASH sample. While SASH and MASH populations are different in some ways, they are similar in that they both deliver PV for low-income populations.

First, the team estimated the standard deviation in the population using the standard error and sample size of Navigant's original sample, SE_O and N_O, as follows:

$$SD^{EST} = SE_O \cdot \sqrt{N_O}$$

$$SD^{EST} = 4.1 \cdot \sqrt{83}$$

$$SD^{EST} = 37.35\%$$

Applying the formulation for a standard error to a new sample drawn from this population, the new standard error SE_N is calculated as:

$$SE_{NEW} = SD^{EST} / \sqrt{N_{NEW}} \quad (1)$$

Navigant's best estimate of the mean DFVR, based on the previous report, is 100 percent. Therefore, the sample size that satisfies the 90/30 condition is the sample size at which the 90 percent confidence interval is plus or minus 30 percent from 100 percent.

The 90 percent confidence width is $SE_{NEW} \cdot 1.65$. Applying this to (1) produces,

$$0.3 = 1.65 \cdot SD^{EST} / \sqrt{N_{NEW}} \quad (2)$$

Solving for new sample size N_{NEW} using the 37.35 percent SD^{EST} calculated above,

$$N_{NEW} = (5.5 \cdot SD^{EST})^2$$
$$= (5.5 \cdot 0.3735)^2$$
$$= 4.22 \textit{ or } 5 \textit{ discrete sites}$$

Therefore, a sample size of five field visits is expected to give 90/30 confidence and relative precision on the DFVR for each program. The team chose to complete two times as many desk reviews as field visits. Because of the small sample size, the evaluation plan included a provision for further field visits and desk reviews if necessary to meet the 90/30 target. However, Navigant did not need to increase sample sizes to meet the confidence and relative precision target.

2.1.2 Segmentation

Navigant used a random sampling approach and segmented the sample to ensure representation across a few key program and performance dimensions. The evaluation used segmentation because the final target sample size was small due to the 90/30 confidence and relative precision target. This approach is different from the approach used in the 2009–2010 evaluation. In the 2009–2010 evaluation, Navigant used a stratified random sample, which split the sample into strata of similar characteristics (e.g., geography, size, etc.). Navigant used a stratified random sample in the previous evaluation based on the sampling requirements for that evaluation. Segmentation is similar to stratification, but the goal of segmentation is to have representation of certain characteristics of the population. Segmentation does not improve statistics over a simple random sample.

The following segmentation approach relates primarily to the desk review. Navigant targeted the field verification sample as a subset of the desk review sample. The segmentation variables for the SASH desk review were:

1. Array size (small versus large)
2. Geographic location (assigned GRID Alternatives' office, including the top five—by number of sites installed—GRID Alternatives' regions)

Navigant selected 3 kW-AC (CEC) as the array size cutoff. Using this system size yields two groups (small and large) with roughly equal total capacity. Navigant also chose to sample from the top five GRID offices (when ranked by number of completed sites in the 2011–2013 timeframe) to ensure geographic representation. Table 2-2 shows the segmentation variables used in the SASH desk review and subsequently used to target the field verification sample. Table 2-3 shows the sample design for the SASH desk review, including the quantity of sample in each segment.

Table 2-2. SASH Segmentation Variables

Array Size (kW-AC [CEC])		Geographic Location
<=3 kW	>3 kW	Bay Area
		Central Valley
		Inland Empire
		Greater Los Angeles
		San Diego

Source: Navigant Consulting, Inc.

Table 2-3. SASH Desk Review Sample Design

Assigned Office	Array Size (kW-AC [CEC])	Sample
Bay Area	Small (<=3 kW)	1
	Large (>3 kW)	1
Central Valley	Small (<=3 kW)	1
	Large (>3 kW)	1
Inland Empire	Small (<=3 kW)	1
	Large (>3 kW)	1
Greater Los Angeles	Small (<=3 kW)	1
	Large (>3 kW)	1
San Diego	Small (<=3 kW)	1
	Large (>3 kW)	1

Source: Navigant Consulting, Inc.

Similarly, the segmentation variables for the MASH desk review were:

1. Array size (small versus large)
2. Climate (coastal versus inland)
3. Interconnection type (NEM versus VNM)

Navigant divided MASH sites into two roughly equal halves by capacity for size segmentation, with small sites under 130 kW-DC (PTC) and large sites greater than 130 kW-DC (PTC). Further segmentation along coastal versus inland climate and NEM versus VNM interconnection type provided representation across system performance and program delivery structure. Table 2-4 shows the segmentation variables used in the MASH desk review verification. Table 2-5 shows the sample design for the MASH desk review, including the sample size in each segment. As with SASH, Navigant targeted the field sample to be a subset of the desk review sample.

Table 2-4. MASH Segmentation Variables

Array Size (kW-DC [PTC])	Interconnection Type			
Climate	**NEM**		**VNM**	
Coastal	<=130 kW	>130 kW	<=130 kW	>130 kW
Inland				

Source: Navigant Consulting, Inc.

Table 2-5. MASH Desk Review Sample Design

Interconnection Type	Inland/Coastal	Array Size (kW-DC [PTC])	Sample
NEM	Coastal	Small (<=130 kW)	1
		Large (>130 kW)	1
	Inland	Small (<=130 kW)	2
		Large (>130 kW)	1
VNM	Coastal	Small (<=130 kW)	1
		Large (>130 kW)	1
	Inland	Small (<=130 kW)	1
		Large (>130 kW)	2

Source: Navigant Consulting, Inc.

2.1.3 Recruiting

The recruiting team attempted to nest the field verification sample within the desk review sample. A fully nested sample would mean that the five sites visited for the field verification are a subset of the 10

sites for which the team completed a desk review. The recruiting team first called the 10 desk review sites to attempt to schedule field verification visits.
The recruiting team was not able to recruit some desk review sites for the field verification visits because of non-response or refusal to participate in the evaluation. If the recruiting team was unable to schedule five desk review sites for field verification visits, they continued calling other randomly sampled sites until they scheduled five field verification visits. The recruiting team scheduled one SASH desk review site for field verification (i.e., only one of five SASH field verification sites was also in the desk review sample—not a fully nested sample).The team scheduled five MASH desk review sites for field verification (i.e., a fully nested sample).

Based on prior evaluation experience with residential fieldwork, the recruiting team offered a $50 gift card to each SASH participant to facilitate recruiting and to minimize dropouts for SASH. MASH site hosts did not receive an incentive because of Navigant's previous experience that property managers are generally willing to host a site visit without an incentive. Navigant recruiters had little difficulty scheduling MASH site visits while SASH customers were generally more difficult to recruit, confirming Navigant's assumptions.

2.1.4 Data Collection Field Guide

The Data Collection Field Guide is included as Appendix A of this report. The field guide details the methodology to collect nameplate data, conduct spot measurements, and verify system installation conditions. The guide provides instructions for accurately completing the data collection forms and details actions to take following data collection.

The field staff collected the following data during the verification site visits:

1. Verify that all assumptions used in the EPBB calculator printout as documented in the site inspection report match the as-installed system characteristics:
    a. Nameplate PV module
    b. Number of modules
    c. Nameplate PV inverter
    d. Number of inverters
    e. Shading derate factors for each month
    f. Tilt
    g. Azimuth
2. Note any damage, evidence of tampering/theft/vandalism
3. Note levels of soiling on surface
4. Read output from inverter (if available)
5. Note any other possible contributing factors to loss (or gain) of production

The Data Collection Field Guide provides more specific information on the data collection forms and methods, specifics on the data collection platform, equipment needs, protocols for collecting/storing data, and quality control methods.

2.1.5 Data Management and Flow

Navigant managed field activities using a tablet-PC-based data collection system called Fulcrum[44] that allows for data entry directly into the electronic database while onsite. Using the Fulcrum software, Navigant developed a data collection form specific to this study. Field technicians carried tablet PCs loaded with the Fulcrum software into the field and entered data following the procedures listed in the form. The tablet synchronized the collected data to a centralized server when in range of a wireless Internet connection. This provided many quality control (QC) benefits:

- Data collected in the field undergoes a near real-time QC process as reviewed by the project manager. The project manager reviews data for incomplete data sets and values that are outside of expected ranges.
- A web-based data warehouse allows all field staff to enter data into a single file, thus avoiding version problems associated with distributed tools, such as Access databases or Excel spreadsheets.
- The analysis team can extract the most up-to-date data at any time to conduct interim analysis or to confirm evaluation results.
- The system is password protected and allows the fieldwork supervisor to assign different permissions for viewing and editing data depending on staff roles (i.e., analysts, recruiters, and field staff all have different levels of access).

The Fulcrum data entry system developed for this study included bounding and data validation for all data points, which helped ensure data integrity. For example, dropdown menus allowed a finite number of possible answers to a particular question, thus keeping data cleaning activities to a minimum. For more information on the data collection procedures see Appendix B.

2.1.6 Site Visits

Navigant-led field crews completed field verifications of five SASH sites and five MASH sites in September 2014. In order to provide consistency across evaluation cycles and reduce training costs, Navigant utilized some of the same field staff who collected data during the 2009–2010 evaluation. These veteran field members led the field crews and provided training and supervision to the full field team.

2.2 IMPACT ANALYSIS METHODOLOGY

This section describes the methodology used to determine the impacts of the SASH and MASH programs. The team completed the impact analysis to meet the following objectives:

[44] http://fulcrumapp.com/

- Produce estimates of the following parameters:[45]
    - DFVR (unitless)
    - Energy production (kWh)
    - Capacity factor (unitless)
    - Demand reduction (California Independent System Operator, or CAISO, peak/IOU peak, kW-AC (meter))
    - Greenhouse gas (GHG) emissions reduction (tons carbon dioxide, or CO_2)
- Assess bill impacts for participating customers ($ per customer)
- Understand the degree to which tenants served by MASH projects receive benefits from the program (completed through bill impact analysis for tenants and NEB analysis)

The following subsections provide more detail on Navigant's approaches for the impact analysis methodology:

- Section 2.2.1—Project Definitions
- Section 2.2.2—Data Sources
- Section 2.2.3—Design Factor Verification Rate
- Section 2.2.4—PV Production Model
- Section 2.2.5—Energy Production
- Section 2.2.6—Capacity Factor
- Section 2.2.7—Demand Reduction
- Section 2.2.8—Greenhouse Gas Emissions Reduction
- Section 2.2.9—Customer Bill Impacts

2.2.1 Project Definitions

Navigant included SASH and MASH projects in the impact analysis with interconnection dates in 2011, 2012, and 2013. Based on discussions with PAs, Navigant used the following criteria to define installed and interconnected projects, according to information available in the tracking databases:

- The team used the Salesforce database for the SASH program; these filters resulted in 3,164 SASH projects interconnected in 2011, 2012, or 2013

[45] These parameters are not listed as key objectives in the analysis. However, they do inform the understanding of the impact of the program and were included in the approved work plan (Navigant. "California Solar Initiative – Biennial Evaluation Studies for the Single-family Affordable Solar Homes (SASH) and Multifamily Affordable Solar Housing (MASH) Low-Income Programs." June 23, 2014). In addition, the energy production is an input into the cost-benefit analysis.

  - Filter "Interconnection Utility Accepted Date" in 2011, 2012, or 2013
  - Filter projects with status of "Installed" or "Completed"
- The team used the PowerClerk database for the MASH program; these filters resulted in 273[46] MASH projects interconnected in 2011, 2012, or 2013
  - Filter "First Incentive Claim Request Review Date" in 2011, 2012, or 2013
  - Filter projects with a status of "Completed" or "Suspended - Incentive Claim Request Review"

It is important to note that the MASH PAs are not consistent in how they assign MASH projects to a specific year for reporting purposes. Thus, the above binning scheme may result in project quantities, installed capacity, and paid incentives different from those reported by the PAs in the *CSI Semi-Annual Expense Reports*.

2.2.2 Data Sources

Navigant used a number of different data sources to accomplish the impact analysis objectives. This section introduces those data sources in a comprehensive list. The data sources are also referenced in subsequent descriptions of the impact methodology. The list below includes a brief description of each data source and the components of the analysis that utilized the data.

- **Program Tracking Databases:** GRID Alternatives tracks SASH program data in a central, web-based repository—a Salesforce database. Each record in Salesforce corresponds to a single SASH project. The database tracks each project through the application process and includes fields such as contact information, rebates, and project status. Some PV array characteristics are available (such as equipment type and quantity, installed capacity, and DF), while others are not. MASH PAs track program data using the PowerClerk database. The PowerClerk database contains similar information, but it contains more detail because the MASH program is more complex.
  - *Data applicability: DFVR, PV Production Model, Capacity Factor*
- **EPBB and Third-Party Inspection Forms:** As part of the application process, each SASH and MASH applicant uses the EPBB calculator available on the Internet[47] to calculate expected performance and program metrics. The applicant saves a PDF or scanned image of the calculated results page (one per array) to document values such as estimated annual production, DF, and incentive amount. The output page also contains key array characteristics. Additionally,

[46] The PowerClerk database includes only Track 1 MASH projects. To include all projects in the analysis, Navigant merged information from 13 Track 2 projects provided by the PAs via a separate data request. The PAs did not provide the data in a consistent format; rather each PA provided spreadsheets and supporting documentation. To introduce consistency and streamline the analysis, Navigant transcribed this information into the same spreadsheet containing the Track 1 PowerClerk data. Thus, where PowerClerk is mentioned throughout this report, both Track 1 and Track 2 projects are included.
[47] http://www.csi-epbb.com/default.aspx

a third party inspects 14 percent of SASH sites and 100 percent of MASH sites. The inspection forms contain a side-by-side comparison of the original EPBB values and those found onsite by the inspector. If differences in measured system characteristics are significant, the inspector re-calculates the EPBB values and submits the corrections to the tracking database.[48]

  - *Data applicability: DFVR, PV Production Model*

- **Weather Data:** Navigant downloaded actual hourly weather data from the California Irrigation Management Information System (CIMIS) for 2011, 2012, and 2013. The network has more than 120 stations spread geographically across California in order to provide relevant meteorological data for making decisions on irrigation practices throughout the state.[49] The data available at CIMIS weather stations contains most of the required inputs to the hourly solar PV model. In addition to this historical data, Navigant used Typical Meteorological Year (TMY) data published by the National Renewable Energy Laboratory (NREL). Navigant used the data available in TMY3 format, which the System Advisor Model (SAM) reads directly. Further information on the weather data is covered in Section 2.2.4.1 and Appendix C.2.
  - *Data applicability: PV Production Model*
- **List of California Climate Zones by ZIP Code:** Navigant used California's official building climate zones (numbered 1–16) throughout the analysis. Navigant assigned each SASH or MASH project a climate zone based on a spreadsheet containing climate zone by ZIP code published by the CEC.[50]
  - *Data applicability: Extrapolation of modeled production*
- **VNM Metered Data:** MASH PAs provided Navigant with interval-metered PV production data for VNM sites. The data contained hourly (and in some cases sub-hourly) kWh production data. Although the data only covers a portion of the MASH sites, the metered data proved valuable during calibration of the PV production model.
  - *Data applicability: Calibration of modeled production*
- **CAISO Peak Load History:** CAISO is a non-profit independent system operator serving California. CAISO oversees the operation of California's overall electric power systems' generation and transmission, as well as electricity markets. CAISO keeps a record of the California-wide system peak for research and planning purposes on its website.[51]
  - *Data applicability: Demand Reduction*
- **E3 NEM Avoided Cost Model:** Energy + Environmental Economics (E3) maintains an avoided cost model spreadsheet tool for calculating avoided costs associated with distributed energy

[48] Allowable tolerances on key project components can be found in the CSI Program Handbook: http://www.gosolarcalifornia.ca.gov/documents/CSI_HANDBOOK.PDF.
[49] http://www.cimis.water.ca.gov/
[50] http://www.energy.ca.gov/maps/renewable/BuildingClimateZonesByZIPCode.xlsx
[51] https://www.caiso.com/Documents/CaliforniaISOPeakLoadHistory.pdf

resources such as solar PV. Navigant referenced the most current version of the model for the GHG scaling factors described in more detail in Section 2.2.8.[52]

  - *Data applicability: Greenhouse Gas Emissions Reduction*

- **Monthly Billing Data:** Each IOU provided Navigant with one year of monthly billing data for SASH customers and those MASH tenant and owner accounts receiving benefits from the PV systems installed in 2011–2013.
  - *Data applicability: Customer Bill Impacts*
- **Rate Tariff Documents:** IOUs publish formal descriptions of each rate schedule. They describe detailed fees and charges for each rate schedule and are essentially a guide for how the IOUs calculate customers' bills each month. For simplicity, Navigant accessed only the rate tariffs in effect as of January 2015, corresponding to the most common rates across the SASH and MASH programs. See Appendix C.1 for more detail on the rates and rate tariffs used in the analysis.
  - *Data applicability: Customer Bill Impacts*
- **Database for Energy-Efficient Resources (DEER) and U.S. Department of Energy (DOE) Prototype Model Load Shapes:** During the 2009–2010 evaluation, Navigant obtained typical single-family residential home load curves for climate zones 3 (coastal) and 13 (inland) courtesy of the DEER team. For consistency, Navigant used those same load shapes for this evaluation, scaled based on estimated annual load for each SASH customer. For MASH load shapes, Navigant used tenant and common electric load shapes derived from the DOE Commercial Prototype Building Model, specifically from the mid-rise apartment building type. More information on load shapes used in this analysis is located in Section 2.2.9.
  - *Data applicability: Customer Bill Impacts*
- **Residential Energy Consumption Survey (RECS):** The U.S. Energy Information Administration (EIA) periodically conducts a national survey of residential energy consumption. The most recent data is from the 2009 RECS survey. Navigant used this detailed data to estimate multifamily average electricity consumption, used for scaling the MASH tenant load shapes.[53]
  - *Data applicability: Customer Bill Impacts*

2.2.3 Design Factor Verification Rate

The goal of the desk review and field verification was to determine the DFVR to 90/30 confidence and relative precision. A secondary metric, Clerical Error Realization Rate (CERR), measures clerical errors that are apparent errors in DF or system characteristics between hard-copy records and the program tracking databases. Neither DFVR nor CERR contributes to other aspects of the impact analysis. These rates are standalone metrics that describe PV installation and record-keeping effectiveness.

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[52] E3 CSI/SGIP Avoided Cost Calculator, dated April 7, 2015.

[53] http://www.eia.gov/consumption/residential/data/2009/ (accessed May, 2015)

DF is the ratio of estimated system summer kWh output[54] (given installed system characteristics and shading) to an estimated optimally configured system[55] for that location using the same equipment. The SASH program uses a modified DF that does not include corrections for the geographic location.[56] In this document, DF refers to both the modified DF for SASH and the regular CSI DF for MASH. If the modified DF is less than 85 percent, the system does not qualify for the SASH program incentive.[57] The MASH program uses system DF and the CEC's AC system rating to determine incentive amounts.[58]

Based on the results of the field verification work, Navigant calculated two separate realization rates relating to DF. DFVR is the ratio of Navigant-verified DF to the DF reported in the program database and indicates how well the database reflects the actual as-installed system configurations (as verified by Navigant field/desk review staff). The equation to calculate DFVR is found in Equation 2-1. DFVR is discussed in Section 2.1.

Equation 2-1. Design Factor Verification Rate

$$DFVR = \frac{DF_{Navigant}}{DF_{Reported}}$$

Where:

$DF_{Navigant}$ = Navigant-calculated DF (Dcorr*Icorr for SASH, Dcorr*Icorr*Gcorr for MASH)[59]

$DF_{Reported}$ = Site-level DF listed in Salesforce (for SASH) or PowerClerk (for MASH)

The team also calculated the CERR, as it sheds light on the error in DF due to system characteristics or DF values entered incorrectly into the database from the third-party inspection forms or EPBB printouts. CERR is defined in Equation 2-2.

Equation 2-2. Clerical Error Realization Rate

$$CERR = \frac{DF_{EPBB}}{DF_{Reported}}$$

Where:

$DF_{EPBB,}$ = Site-level DF based on latest PA EPBB/field inspection worksheet (FIWS) (weighted by array kW-AC [CEC])

$DF_{Reported}$ = Site-level DF listed in Salesforce (for SASH) or PowerClerk (for MASH)

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[54] The summer period is the defined as May 1 through October 31, per the *CSI Calculator v6 User Guide* (http://www.csi-epbb.com/CSICalculatorV6UserGuide.pdf).

[55] As defined in the *CSI Calculator v6 User Guide* (Ibid).

[56] The reasoning for this difference is contained in the SASH D.07-11-045 Section 4, Performance Requirements.

[57] Ibid. Originally the modified DF threshold was set at 95 percent, but it was changed to 85 percent in 2010–2011.

[58] Ibid.

[59] Dcorr is the Design Correction Factor, Icorr is the Installation Correction Factor, and Gcorr is the Geographic Correction factor. Each of these comes from the EPBB calculator printouts.

2.2.4 PV Production Model

Navigant developed a detailed PV production model to simulate hourly energy production from SASH and MASH PV systems. Navigant used simulated hourly energy production as the basis for completing all of the impact analysis objectives except calculating the DFVR. The PV production model used to simulate hourly energy production is described in the next three subsections as follows:

- Section 2.2.4.1 describes the simulation engine and the data sources for the model inputs and weather files.
- Section 2.2.4.2 explains the extrapolation of the model results for the subset of PV arrays to those sites without modeled results.
- Section 2.2.4.3 outlines how the model was calibrated using available metered data.

2.2.4.1 Data Sources and Inputs

The analysis team selected NREL's SAM[60] to conduct the 8,760 hourly[61] PV production modeling. Using the built-in TMY weather data and actual weather data from the CIMIS stations, the analysis team generated four hourly output shapes for each array for which installation characteristics were available (covering approximately 56 percent of SASH sites and 100 percent of MASH sites):

1. TMY
2. 2011 (actual weather)
3. 2012 (actual weather)
4. 2013 (actual weather)

[60] https://www.nrel.gov/analysis/sam/

[61] In an 8,760 hourly model, the software estimates PV production in each hour of a year, given 8,760 hours (24 hours per day times 365 days per year) in a (non-leap) year. Navigant accounted for the fact that 2012 was a leap year after modeling was complete by simply repeating February 28 as February 29.

Appendix C.2 provides more detail regarding weather data processing. Table 2-6 shows how Navigant incorporated the model results into various aspects of the impact analysis.

Table 2-6. Weather Data Used for Each Part of Impacts Analysis

Analysis	TMY Weather	Actual Weather	Notes
Energy	X	X	Actual and typical weather provide prospective and retrospective views on energy production.
Capacity Factor	X		Capacity factor estimated with consistent TMY weather across the same amount of time (8,760 hours) allows comparison of installed capacity between program years.
Peak Demand		X	Peak demand reductions are specific to a point in time and require actual historic data to calculate.
Bill Impacts	X		Navigant used bill impacts to calculate NEBs and cost-benefit ratios, which are forward-looking. The billing analysis estimates savings using current rate tariffs for simplicity and back-calculates typical first-year savings so TMY is the appropriate weather source.
NEBs	X		Forward-looking analysis only.
Cost-Benefit	X		Forward-looking analysis only.

Source: Navigant Consulting, Inc.

The SASH and MASH PAs provided inputs via program tracking databases and through responses to formal data requests. These inputs included the PV and inverter system characteristics that SAM required to simulate the system performance. GRID Alternatives provided Navigant with access to the Salesforce database to access SASH data. In addition, GRID provided copies of PDF EPBB printouts and copies of third-party inspection worksheets. The other PAs (CSE, PG&E, and SCE) provided the input data for the MASH sites in their respective territories via the PowerClerk database as well as through PDF versions of CSI EPBB calculator printouts.[62] Appendix C.4 includes a more comprehensive list of model inputs.

[62] The current CSI EPBB calculator is available at: http://www.csi-epbb.com/

2.2.4.2 Extrapolation

The Salesforce database tracks the equipment quantity, make and model of the equipment, and overall array capacity for the SASH program. Using text mining tools within the R programming language, Navigant scraped the detailed PV system characteristics' data (e.g., tilt, azimuth, shading, and PV standoff) from EPBB printouts for about half of the SASH sites.[63] For further detail on the PDF scraping techniques, refer to Appendix C.3. In cases where there were multiple EPBB printouts for the same array, Navigant selected the printout with the most recent date for the scraping exercise. Using the model results from the more detailed input data, Navigant developed 8,760 hourly generation shapes by climate zone for each of the weather files (2011–2013 weather files and TMY weather files). Navigant then scaled those shapes based on system capacity for sites without modeled results.

For the MASH program, the PowerClerk database contains relatively detailed information on PV system characteristics, including equipment quantity, make, model, array tilt, and azimuth. However, PowerClerk does not provide information on monthly array shading or array standoff (the distance between the roof and the module), both of which are key inputs to the SAM model.[64] Using the same text mining tools as were used for SASH, Navigant successfully scraped data from the existing EPBB printouts for 52 percent of the MASH sites, specifically to account for the lack of shading and PV standoff data. The team then calculated typical values by climate zone for shading and PV standoff and applied those values (by climate zone) to the arrays' missing data. Thus, the final model output results for MASH contain 100 percent-modeled output, using a hybrid of actual and interpolated inputs.

The next step in generating realistic 8,760 hourly production curves was to account for the utility interconnection dates of each system. Navigant set hourly production values to zero for all hours before the installation date for the 2011–2013 modeled weather data. Navigant used these abbreviated 2011–2013 production shapes to calculate actual year energy and peak demand impacts. Navigant used modeled results generated based on TMY data as full year production when calculating typical annual impacts.

[63] Scraping involves using computer programming tools to extract data out of documents or web pages that are designed for human viewing rather than the ease of data processing. The process was difficult because PAs provided the EPBBs in various and inconsistent formats—some were scanned images, others were printed PDF versions, and some others were HTML files. For more information regarding data quality issues encountered during the analysis see Appendix A.

[64] While shading values do appear in the PowerClerk database on each MASH application summary, they were not exportable into a spreadsheet format due to a database/system error as of May 2015.

2.2.4.3 Calibration

Navigant used interval-metered data available for a subset of the MASH sites to calibrate the 8,760 hourly modeled results. Navigant calibrated the results to correct for inherent modeling errors. Such errors could include:

- Error in converting solar radiation from actual weather to the TMY format SAM requires[65]
- Monthly to hourly shading conversion error
- Incorrect AC-DC derate factors for both SASH and MASH PV arrays[66]

Although the team had difficulty matching VNM meter data and account numbers with specific MASH applications, the team was able to match metered data with program data for 60 sites, representing about 22 percent of installed MASH projects between 2011 and 2013. Navigant used identical approaches for modeling SASH and MASH sites; because there is no reason to believe SASH modeling errors would be substantially different from those encountered for MASH, Navigant applied calibration factors calculated using the VNM data to both SASH and MASH model results.

Navigant calculated and applied calibration factors by inland versus coastal climate zones. The calibration factors consisted of an array of 288 values (12 months of the year by 24 hours in each day). After determining the calibration factors, Navigant added them hour by hour to the modeled data to correct for the modeling error for sites with both VNM metered data and modeled hourly data. See Appendix C.5 for tables containing the calibration factors.

2.2.5 Energy Production

Estimating energy production is one of the objectives of the impact analysis. Understanding energy production is important because it provides a metric to compare the scale of the SASH and MASH programs against previous years or other programs. Navigant defines energy production in this evaluation as the annual electrical energy produced by program-incentivized PV arrays.

Navigant calculated energy production using two methods: using model results derived from TMY weather and using results derived from actual historic weather data for 2011–2013. Using these results, Navigant generated two estimates of energy production by year for 2011–2013:

1. Typical annual energy production starting the first full year after a system's installation date
2. Actual annual energy production as seen by the grid in 2011–2013

Navigant calculated energy production by summing the 8,760 hourly production curves by IOU and quarter. The annual production curve generated using TMY data includes a full year of data for each

[65] The actual year weather (from the CIMIS stations) contains only total horizontal radiation. SAM requires that radiation be split apart into beam and diffuse components. Estimating beam and diffuse from the total involves an empirical formula and may introduce error.
[66] Navigant accounted for 2012 as a leap year when comparing TMY and actual year data.

array, while the historic production curves for 2011–2013 include production data only in the hours after the system's interconnection date.

2.2.6 Capacity Factor

Producing estimates of capacity factor (CF) is also one of the objectives of the impact analysis. CF is a ratio of the actual output of a system during a specified timeframe to the theoretical maximum rated output of that system during the same timeframe. CF is a metric that is used in the power industry to describe the reliability of power plants. For PV generation, it can be used to compare efficacy and available solar resource across one or many PV systems. In simple terms, it is the equivalent fraction of the time the modules are producing the output rated at the standard testing conditions (STC) of 1,000 W/m^2 at a 25°C rating.[67] Navigant calculated CF using Equation 2-3:

Equation 2-3. Capacity Factor

$$CF_{int} = \frac{\sum_{i=1}^{int} kWh_{prod,i}}{\sum_{i=1}^{int} STC_{site}}$$

Where:
CF_{int} = CF calculated over a specific time interval
kWh_{prod} = Actual kWh production during hour i
STC_{site} = kW-DC (STC) rating for the site

2.2.7 Demand Reduction

Another objective of the impact analysis is to estimate peak demand reduction. Understanding contribution to peak demand reduction is important because it provides a sense for how well the PV production coincides with the system-wide annual peak demand on the electric grid.

Navigant calculated the SASH and MASH demand reduction impacts during the CAISO peak hours by summing the modeled (actual weather) kWh energy production during those hours by IOU and year. The term peak hour refers to the hour during which the actual system-wide peak demand occurred according to CAISO. The PV production model's 8,760 hourly outputs (described in Section 2.2.5) are in Pacific Standard Time (PST) because SAM does not account for daylight savings time. The analysis

[67] CEC-AC rating is equal to the number of modules times the module PVUSA Test Conditions (PTC) rating times the inverter efficiency.

accounted for daylight savings before summing production over the peak hour.[68] Peak demand events for 2011–2013 are listed in Table 2-7.[69] For utility peak definitions and impacts, see Appendix D.

Table 2-7. CAISO Peak for 2011–2013

Year	CAISO Peak
2011	September 7, 4:00 p.m. to 5:00 p.m. (PDT)
2012	August 13, 3:00 p.m. to 4:00 p.m. (PDT)
2013	June 28, 4:00 p.m. to 5:00 p.m. (PDT)

Source: CAISO

In addition, Navigant calculated a peak capacity factor for each CAISO peak event, which is the ratio of peak power production to the total capacity rating of the PV arrays installed and interconnected before the date of the peak event.[70] The peak capacity factor demonstrates how favorable conditions were for solar power production during the peak time and accounts for factors such as geographic distribution of the arrays, tilt, azimuth, shading, cloud cover, and time of day.

2.2.8 Greenhouse Gas Emissions Reduction

Estimating GHG emissions reductions was also an objective of this study. For this evaluation, Navigant defined GHG emissions reductions as the amount of CO_2 (in tons) offset by SASH or MASH incentivized PV arrays. Navigant based GHG emissions reductions on the E3 CSI/Self-Generation Incentive Program (SGIP) Avoided Cost Calculator, which calculates emissions from a mix of electricity generation sources across the state of California.[71] The tool lists annual average market heat rate by year as well as the

[68] Pacific Daylight Time (PDT) is only observed during certain months of the year; Pacific Standard Time (PST) is observed the rest of the year. The CAISO peak generally occurs during the summer when PDT is in effect.
[69] For the 2011–2013 CAISO peak hour definition, Navigant used the hour containing each annual peak time as defined on the CAISO website: https://www.caiso.com/Documents/CaliforniaISOPeakLoadHistory.pdf.
[70] The team calculated the peak capacity factor using AC (CEC) rating for SASH and DC (PTC) rating for MASH based on the format of the data from the PAs.
[71] E3 CSI/SGIP Avoided Cost Calculator, dated April 7, 2015.

natural gas carbon content. Table 2-8 shows the calculation by which Navigant arrived at the tons per MWh conversion factor used in calculating GHG impacts.

Table 2-8. Annual GHG Conversion Factors as Calculated from E3 Tool

Year	Average California Market Heat Rate* (MMBtu/MWh) [A]	Natural Gas Carbon Content (tons/MMBtu) [B]	GHG Conversion Factor (tons/MWh) [A] x [B]
2011	6.57	0.0585	0.384
2012	8.38		0.490
2013	7.70		0.450

*The heat rate is the amount of energy used by an electrical generator or power plant to generate one megawatt-hour (MWh) of electricity.

Source: Navigant analysis of E3 CSI/SGIP Avoided Cost Calculator, dated April 7, 2015

2.2.9 Customer Bill Impacts

Assessing bill impacts for participating customers is also a stated impact analysis objective. Bill impacts are defined as the annual reduction in a customer's electricity bill (in U.S. dollars per customer) attributable to the PV system incentivized by the SASH or MASH program. Navigant estimated the bill impacts for SASH and MASH participants for 2011, 2012, and 2013. The MASH participant bill impacts included impacts for MASH tenants and MASH building owners.

The team's calculations for bill impacts take into account specific factors such as installed PV capacity, typical local weather conditions, unique rate schedules, and California Alternate Rates for Energy Program (CARE) status. The analysis differs slightly for SASH and MASH, though the overall framework is the same. For both programs, the bill impact analysis fundamentally involves three steps, which are outlined in more detail below.

1. Collect and format rate class data
2. Develop hourly pre-PV installation and post-PV installation energy consumption
3. Determine annual bill impacts

Step 1. Collect and format rate class data. Rate structures vary across IOUs, and each IOU has its own definition of billing metrics such as baseline use, tiers, and time-of-use periods. Residential rate structures in California are quite complex. For example, baseline use definition can depend on many factors including home heating type, weather zone, and time of year. As a result, Navigant simplified the analysis by focusing on each IOU's primary rate classes. Navigant defined primary rate classes such that they cover 90 percent of participant systems with the minimum number of rate classes. Lastly, because rate structures change over time, Navigant used the most current rate structures available at the time of the analysis (late 2014/early 2015) to calculate the bill impacts.

PV customers, both VNM and NEM, pay non-bypassable charges in much the same way as customers without PV systems. The key difference is that the VNM and NEM tariffs determine charges on net consumption rather than gross consumption.[72] Non-bypassable charges are per kWh fees levied to cover certain costs not directly related to generation or distribution. Examples of non-bypassable charges include:

- Department of Water Resources Bond Charges
- Power Charge Indifference Adjustment
- Competition Transition Charge
- Nuclear Decommission Charge
- Regulatory Asset Charge
- Public Purpose Program
- Energy Costs Recover Account
- New System Generation Charge

The bundled total rates listed in the tariffs include these non-bypassable charges. Because Navigant used the bundled rates in conjunction with estimated net energy consumption to calculate bill impacts, the team did not separately account for non-bypassable charges.

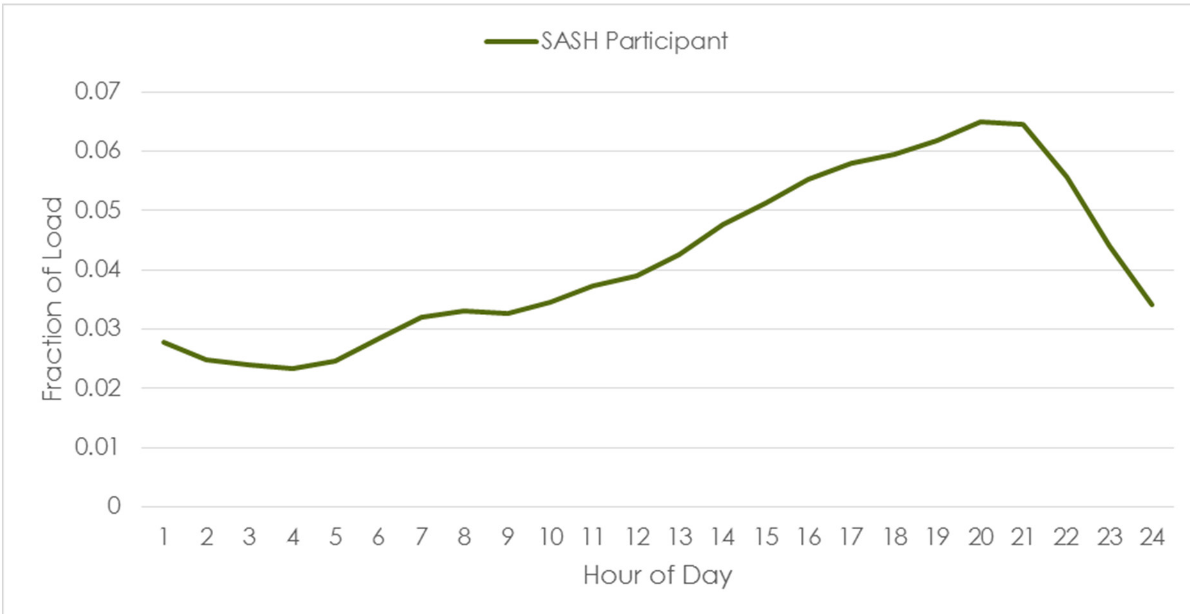
Step 2. Develop hourly pre-PV installation and post-PV installation energy consumption. Navigant estimated pre-PV installation and post-PV installation energy consumption for each participant using scaled 8,760 load shapes with SAM-modeled hourly generation curves. For both SASH and MASH, Navigant normalized the load shapes and scaled them based on estimated annual load for each home, unit, or common area.

For the SASH program, the team used participant load shapes from the DEER models' hourly energy load shapes for single-family homes—the same load shapes used in the 2009–2010 evaluation. Figure 2-1 shows the SASH 8,760 load shape averaged to a single day for illustration. Based on interviews with GRID Alternatives, Navigant assumed that SASH installers sized the PV systems, on average, to meet

[72] http://www.cpuc.ca.gov/PUC/energy/DistGen/netmetering.htm

77.5 percent of the site's annual energy consumption and scaled the load shape accordingly for each site.[73]

Figure 2-1. SASH 24-Hour Normalized Pre-PV Installation Load Shape



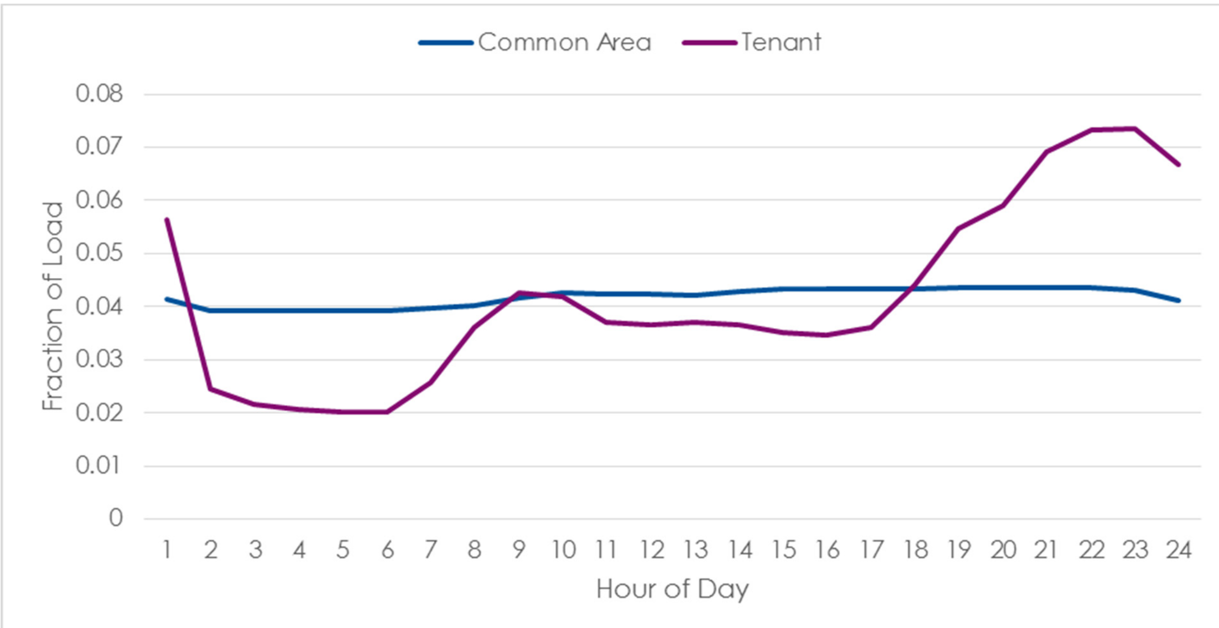
Source: DEER Single-Family Model load shapes used and described in Navigant's 2009–2010 analysis

For MASH, the analysis team used separate 8,760 load shapes for multifamily tenants and common areas based on the U.S. DOE's Prototype Mid-Rise Apartment model.[74] Navigant based tenant allocations on available generating capacity and square footage. Navigant assumed MASH tenant loads such that the average tenant load equals California's multifamily tenant average load, derived by analyzing the most recent RECS data.[75] For MASH common loads, Navigant assumed a PV generation to load ratio of 75 percent based on data provided by the PAs (i.e., Navigant assumed that the annual common area-

[73] Based on interviews with stakeholders, which determined the range of PV sizing as 70–85 percent of load on an annual basis.
[74] http://www.energycodes.gov/commercial-prototype-building-models
[75] Navigant analysis of the EIA's 2009 RECS Microdata: http://www.eia.gov/consumption/residential/data/2009/. The analysis involved filtering the microdata for California results only, further filtering for apartments, and then simply averaging the annual kWh usage for all respondents, which came to 4,151 kWh.

allocated PV generation is, on average, equal to 75 percent of common area load). Figure 2-2 shows the MASH tenant and common area (owner) 8,760 load shapes averaged over 24 hours for illustration.

Figure 2-2. MASH 24-Hour Normalized Pre-PV Installation Load Shapes Used for Tenant and Common Area



Source: DOE Commercial Prototype Building Model for Mid-Rise Apartments[76]

After calculating the scaled load shapes to represent the pre-PV installation energy consumption, Navigant subtracted the SAM-modeled hourly PV generation production shapes hour by hour from the scaled load shapes to estimate the post-PV energy consumption. Navigant then averaged the pre- and post-PV energy profiles by:

- PA
- Climate zone
- Install year
- Generation offsetting tenant load versus common area (owner) load (MASH only)
- Third-party-owned versus host-owned (MASH only)
- Owner type (MASH only)

Step 3: Determine annual bill impacts. To estimate annual bill impacts, Navigant applied the primary rate classes to the hourly pre-PV installation and post-PV installation energy consumption curves. The team calculated the difference between pre- and post-bill amounts to determine the savings. The analysis

[76] https://www.energycodes.gov/commercial-prototype-building-models.

team then used participation rates for each rate class to weight the average annual bill impact by climate zone, PA, year, stakeholder (host customer or system owner), and program (SASH or MASH). See Appendix C for detailed tables on rate structure proportions and CARE versus non-CARE assumptions.

2.3 COST-BENEFIT ANALYSIS METHODOLOGY

This section describes the approach for determining the cost-effectiveness of the SASH and MASH programs. The team completed the cost-benefit analysis of SASH and MASH projects to meet the following objectives:

- Calculate the benefits and costs according to conventional cost-effectiveness tests
- Assess NEBs of SASH and MASH program elements and calculate modified cost-effectiveness tests

Decision 09-08-026[77] adopts a methodology assessing the costs and benefits of distributed generation, including the CSI. The decision adopted general policies and principles for cost-benefit methods used to analyze distributed generation; those principles, along with how they were included in the analysis, are summarized in the bullet points below:

- Distributed generation projects and programs should be analyzed using three tests described in the SPM,[78] namely, the Participant Cost Test (PCT), the Total Resource Cost (TRC) Test (including its variant, the Societal Cost Test, or SCT), and the Program Administrator Cost (PAC) Test.
    - **SASH/MASH Cost-Benefit Analysis:** The analysis included the three tests (and the SCT) mentioned in the Decision. In addition to these tests, Navigant also used the Ratepayer Impact Measure (RIM) Test in this analysis.[79]
- The Decision summarized the variables for each of the tests.
    - **SASH/MASH Cost-Benefit Analysis:** The team met with the CPUC to discuss the variables for each of the tests. See Appendix 0.

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[77] California Public Utilities Commission, Decision Adopting Cost-Benefit Methodology for Distributed Generation, August 20, 2009. http://docs.cpuc.ca.gov/word_pdf/FINAL_DECISION/105926.pdf.

[78] Navigant's formulation of the cost-benefit tests followed the 2001 California Standard Practice Manual (California Public Utilities Commission. October 2001. "California Standard Practice Manual: Economic Analysis of Demand-Side Programs and Projects." http://www.cpuc.ca.gov/NR/rdonlyres/004ABF9D-027C-4BE1-9AE1-CE56ADF8DADC/0/CPUC_STANDARD_PRACTICE_MANUAL.pdf) and the subsequent 2007 SPM Clarification Memo (California Public Utilities Commission. 2007. "2007 SPM Clarification Memo." http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CB8QFjAAahUKEwjstqTj6PbHAhUF2R4KHbFAD_o&url=http%3A%2F%2Fwww.cpuc.ca.gov%2FNR%2Frdonlyres%2FA7C97EB0-48FA-4F05-9F3D-4934512FEDEA%2F0%2F2007SPMClarificationMemo.doc&usg=AFQjCNFjn7azEsLkWad-f8ntThZoshxBWg) .

[79] The tests to be included in the SASH/MASH Cost-benefit Analysis were listed in the approved work plan. Navigant. "California Solar Initiative – Biennial Evaluation Studies for the Single-family Affordable Solar Homes (SASH) and Multifamily Affordable Solar Housing (MASH) Low-Income Programs." June 23, 2014.

- The cost-benefit tests should use the avoided cost methodology developed byE3.
    - **SASH/MASH Cost-Benefit Analysis:** Navigant used the most current E3 Avoided Cost Model that was available at the time of this analysis.[80]
- The method used by Itron in its SGIP Year 6 Impact Report should be used to determine the collective transmission and distribution investment deferrals of all distributed generation facilities.
    - **SASH/MASH Cost-Benefit Analysis:** Navigant's analysis captures avoided costs, including transmission and distribution, out to 2032, while the Itron report focused on historic transmission and distribution investment deferrals. As such, Navigant relied on the E3 Avoided Cost model's prospective avoided transmission and distribution costs rather Itron's historic costs.
- All relevant environmental benefits currently used in evaluation of energy efficiency programs should be included in the cost-benefit models, whether or not their impacts result from regulation or compliance with state or federal law.
    - **SASH/MASH Cost-Benefit Analysis:** The analysis includes benefits from avoided CO_2 emissions.
- The cost-benefit analysis of distributed generation programs should include a qualitative analysis of the market transformation effects of these distributed generation programs.
    - **SASH/MASH Cost-Benefit Analysis:** The SASH/MASH evaluation did not include an analysis of the market transformation effects, as it was not within the scope of this evaluation.
- Bill credits under NEM and energy exported to the grid by distributed generation facilities should be included as costs and benefits of NEM in the cost-benefit tests, where appropriate.
    - **SASH/MASH Cost-Benefit Analysis:** Navigant's customer bill impact analysis includes considerations for NEM and non-bypassable charges relevant to PV customers.

The remainder of this section is organized as follows:

- Section 2.3.1—Cost-Benefit Tests
- Section 2.3.2—Installation Groups
- Section 2.3.3—Cash Flows
- Section 2.3.4—Other Key Inputs
- Section 2.3.5—Non-Energy Benefits

[80] E3 provided Navigant with a version of the E3 Avoided Cost Model that is documented as "Update 2013 NEM Model for 2014 SGIP and MASH/SASH Evaluations" with a date-stamp of April 7, 2015.

2.3.1 Cost-Benefit Tests

For each of the low-income solar programs, Navigant calculated cost-benefit ratios and net benefits for five cost tests. Cost-benefit ratios are informative because they show the value of monetary benefits relative to the value of monetary costs, as seen from various stakeholder perspectives, while net benefits provide the total benefits less all costs. The 2001 SPM[81] defines each test as follows:

- **TRC Test:** "The Total Resource Cost Test measures the net costs of a demand-side management program as a resource option based on the total costs of the program, including both the participants' and the utility's costs."
- **SCT:**[82] The Societal Cost Test is a variant on the TRC. "The Societal Test differs from the TRC test in that it includes the effects of externalities (e.g., environmental, national security), excludes tax credit benefits, and uses a different (societal) discount rate."
- **PAC Test:** "The Program Administrator Cost Test measures the net costs of a demand-side management program as a resource option based on the costs incurred by the program administrator (including incentive costs) and excluding any net costs incurred by the participant. The benefits are similar to the TRC benefits. Costs are defined more narrowly."
- **PCT:** "The Participants Test is the measure of the quantifiable benefits and costs to the customer due to participation in a program. Since many customers do not base their decision to participate in a program entirely on quantifiable variables, this test cannot be a complete measure of the benefits and costs of a program to a customer." In the case of MASH projects, the PCT includes costs and benefits for both the owners and tenants.
- **RIM Test:** "The Ratepayer Impact Measure (RIM) test measures what happens to customer bills or rates due to changes in utility revenues and operating costs caused by the program. Rates will go down if the change in revenues from the program is greater than the change in utility costs. Conversely, rates or bills will go up if revenues collected after program implementation are less than the total costs incurred by the utility in implementing the program. This test indicates the direction and magnitude of the expected change in customer bills or rate levels."

2.3.2 Installation Groups

To streamline the cost-benefit analysis while maintaining fidelity in financing structures and applicable input assumptions, Navigant grouped PV systems into installation groups. These groupings ensured that cost-benefit results used the appropriate discount rates, debt/equity fractions, tax environments, retail rates, metering charges, energy allocations among tenant and owners, and avoided costs for the relevant participants. Navigant grouped system installations according to the following characteristics:

- Customer type (residential, commercial, government, and non-profit)
- Climate zone

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[81] California Public Utilities Commission. October 2001. "California Standard Practice Manual: Economic Analysis of Demand-Side Programs and Projects." http://www.cpuc.ca.gov/NR/rdonlyres/004ABF9D-027C-4BE1-9AE1-CE56ADF8DADC/0/CPUC_STANDARD_PRACTICE_MANUAL.pdf.

[82] It is important to note that the CPUC has not adopted the SCT; however, it is included in D.09-08-026.

- Installation year
- Ownership structure (third-party-owned or host-owned MASH projects)
- Owner common area load or tenant load offset by PV generation (for MASH projects)
- Utility
- VNM or NEM (for applying metering charges to SCE MASH projects)

Homeowners were the only owners of SASH projects because TPO systems were not eligible to receive SASH funding during the time period assessed (2011–2013). Therefore, SASH projects fall into the residential customer type classification.

Table 2-9 shows the percentage of MASH installed PV capacity by owner type. As displayed, the majority of MASH systems were third party owned. For each of the host-owned MASH projects, Navigant reviewed public sources to determine whether the host-owner was a commercial, government, or non-profit entity.[83] This designation influenced the financing structures assumed for each entity. Navigant had a 95 percent success rate at identifying the owner type for host-owned systems and used the commercial designation for all non-identified owners.

Table 2-9. Percentage of MASH Installed PV Capacity by Owner Type

Owner Type	% of MASH Installed kW-DC (STC)
Third-Party Owned	71%
Commercial	18%
Government	4%
Non-Profit	8%

Note: Totals may not equal 100 percent due to rounding.

Source: Navigant Consulting, Inc.

2.3.3 Cash Flows

For each program year between 2011 and 2013 and for various stakeholder perspectives, Navigant calculated the total stream of monetary costs and benefits over the PV system's 20-year lifetime. Navigant relied on processed outputs from multiple tools and databases to use as input to Navigant's Cost-Effectiveness Calculator.

Table 2-10 shows the cash flows, the source of each cash flow, and the assignment of program costs to each of the cost tests, consistent with the SPM. Appendix 0 contains a detailed list of cost-benefit inputs with their sources. The team assumed the net-to-gross ratio was 100 percent for this study, implying that no free ridership occurred in these programs. In this analysis, the TRC test and the SCT differed due to

[83] Navigant reviewed databases from the State of California Franchise Tax Board, the California Secretary of State's active business listings, and the State of California Department of Justice's Registry of Charitable Trusts to determine the owner type for each MASH system. In addition, Navigant reached out to the CPUC and PAs for assistance with this categorization.

discount rates (see Table 2-26) and the forecasted cost of carbon. Navigant calculated cost-effectiveness with and without the inclusion of NEBs. Lastly, MASH participants in SCE's service territory that rely on VNM incur daily metering costs, which Navigant included in the cost tests.

Table 2-10. Cash Flows, Sources, and Assignments by Cost Test

Cash Flow	Source	TRC	SCT	PAC	PCT	RIM
Bill Reductions	Navigant's Bill Impact Analysis Tool	Transfer	Transfer	N/A	Benefit	Cost
Avoided Costs	E3's NEM Avoided Cost Model	Benefit	Benefit	Benefit	N/A	Benefit
CSI Incentives[1]	PowerClerk and Salesforce database	Transfer	Transfer	Cost	Benefit	Cost
Administrative Costs	PAs[84]	Cost	Cost	Cost	N/A	Cost
Metering Costs[2]	SCE rate schedules[85]	Cost	Cost	N/A	Cost	N/A
Participant Ownership Costs	Equipment and installation costs: PowerClerk and Salesforce database; Other ownership costs: E3's CSI Single-Installation Cost-Effectiveness Tool	Cost	Cost	N/A	Cost	N/A
Participant NEB[3]	Modified TecMarket Works' LIPPT Tool	Benefit	Benefit	N/A	Benefit	N/A
Utility NEB[3]	Modified TecMarket Works' LIPPT Tool	Benefit	Benefit	Benefit	N/A	Benefit

1. Incentives are a transfer payment in the TRC and SCT tests because they are a benefit to customers and a cost to the utility, so they cancel each other out.
2. Metering costs are only applicable to meters associated with SCE MASH VNM accounts.
3. Navigant provides cost test results with and without NEBs.

Source: Navigant Consulting, Inc.

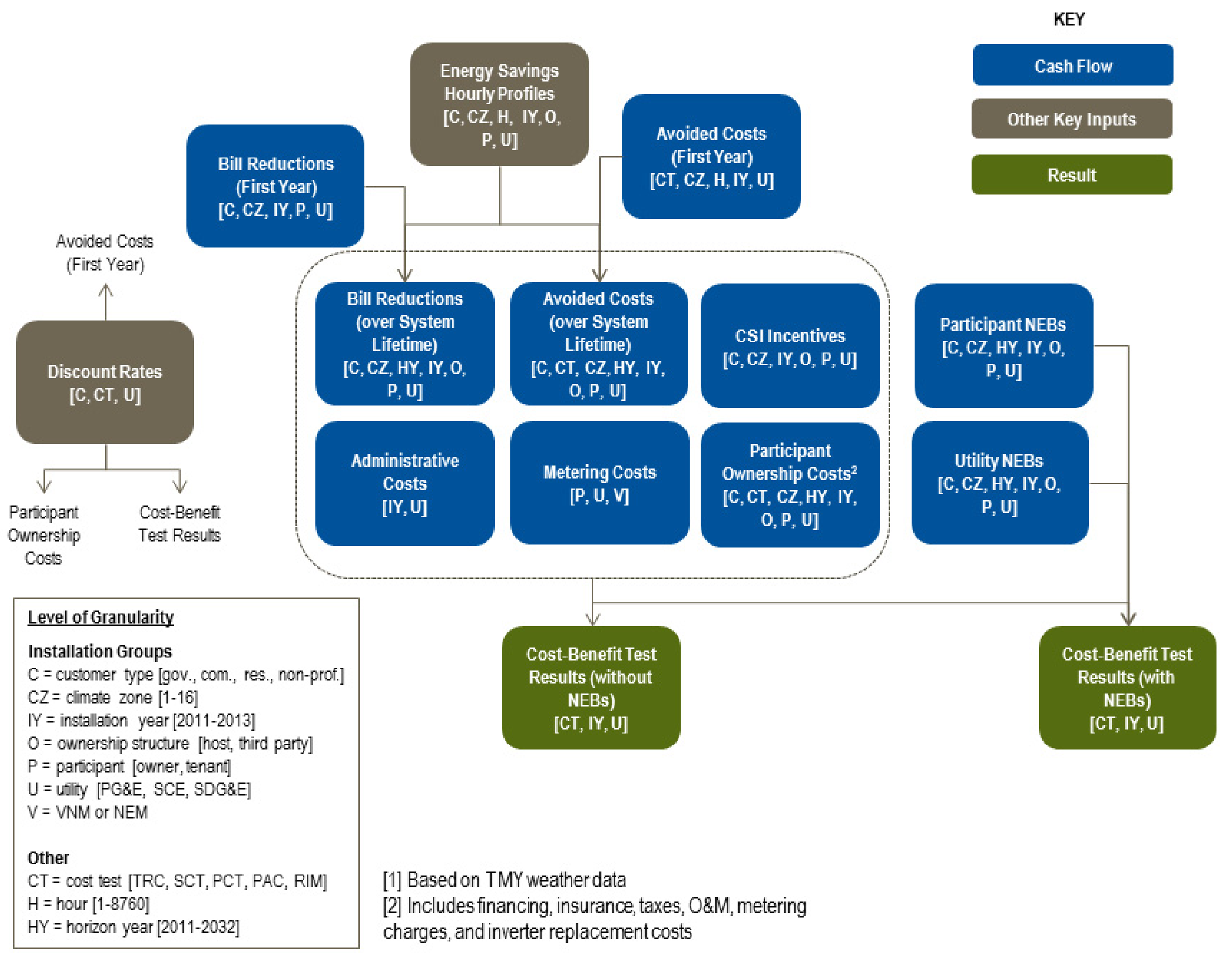
The team imported the cash flows, along with other key model inputs and considerations such as discount rates, inflation rates, and PV output degradation rates, into the Navigant Cost-Effectiveness Calculator. For details on other inputs and assumptions, see Appendix C.8.

Figure 2-3 shows the main model inputs and calculation steps. Navigant created separate input datasets for SASH and MASH and ran the calculator for each program. The Cost-Effectiveness Calculator accepts very granular data as inputs (see Appendix C), from which it calculates the cost and benefit streams. The

[84] The PAs provided administrative costs in response to Navigant's data request dated October 28, 2014. Much of the data they provided appeared to be excerpts from the *CSI Semi-Annual Expense Reports*.
[85] PG&E and SDG&E customers do not incur metering costs.

calculator then aggregates the cost and benefit streams to the level of the IOUs and installation years, and calculates totals across the IOUs and installation years.

Figure 2-3. Cost-Benefit Data Flow Diagram



Source: Navigant Consulting, Inc.

2.3.3.1 Bill Reductions

Section 2.2.9 describes Navigant's methodology for calculating bill savings for years 2011–2013. To forecast bill savings between the years 2014 and 2032, Navigant used the tier- and rate-class-specific forecasts (where available) provided by the IOUs to escalate the bill savings over the 20-year lifetime of the PV systems.[86] These bill savings forecasts accounted for a 1.25 percent per year degradation in PV

[86] Rate forecasts provided by SCE and PG&E in response to Navigant's data request dated October 15, 2014. The files the IOUs sent were named: PG&E – 12-29 RESPONSE (EXCEL FILE) and SCE – CONFIDENTIAL Q.8 ATTACHMENT – SCE RETAIL RATES.PDF

output. The levelized bill savings (see Sections 2.2.9 and 4.3) also relied on the relevant discount rates by cost test and stakeholder.

From the bill savings analysis, Navigant calculated the effective avoided retail rates forecasted for each installation group over the 20-year system lifetime. Table 2-11 provides the SASH levelized avoided retail rates (where the levelization period is 20 years), while Table 2-12 provides the MASH levelized retail rates for tenants and owners.

Table 2-11. SASH Levelized Retail Rates ($/kWh)

Install Year	PG&E	SCE	SDG&E	Wtd. Avg.
2011	0.16	0.16	0.22	0.17
2012	0.16	0.17	0.22	0.17
2013	0.16	0.18	0.25	0.19
Wtd. Avg.	**0.16**	**0.17**	**0.23**	**0.17**

Source: Navigant Consulting, Inc.

Table 2-12. MASH Tenant and Owner Levelized Retail Rates ($/kWh)

Tenant

Install Year	PG&E	SCE	SDG&E	Wtd. Avg.
2011	0.19	0.20	0.24	0.21
2012	0.25	0.21	0.19	0.23
2013	0.17	0.19	0.18	0.18
Wtd. Avg.	**0.21**	**0.20**	**0.22**	**0.21**

Owner

Install Year	PG&E	SCE	SDG&E	Wtd. Avg.
2011	0.31	0.26	0.31	0.29
2012	0.29	0.27	0.33	0.28
2013	0.31	0.28	0.30	0.29
Wtd. Avg.	**0.31**	**0.27**	**0.32**	**0.28**

Source: Navigant Consulting, Inc.

Differences in system orientation, climate zone, and mix of customers on different rate classes caused the variance in levelized retail rates among installation years. For MASH, the mix of customers on different rate classes varied considerably between installation years in some instances.

2.3.3.2 Avoided Costs

Navigant used the E3 NEM Avoided Cost Model[87] to generate hourly avoided costs for each IOU, climate zone, and year between 2011 and 2032. The team updated the E3 model with IOU-specific

[87] Documentation related to the previous release of the E3 NEM Avoided Cost Model is accessible at https://www.ethree.com/public_projects/cpucNEM.php. However, Navigant used the draft version released by E3 on April 7, 2015, which was the most recent version available at the time of the project team's analysis. This draft was provided by E3 after discussions between Navigant and their avoided cost team.

discount rates (shown in Table 2-26) and used the U.S. Environmental Protection Agency's (EPA's) social cost of carbon, as shown in Table 2-13, for the avoided costs used in the SCT test.[88,89]

Table 2-13. Cost of Carbon Included in Avoided Costs ($/short ton CO_2 equivalent)

Year	EPA (SCT Test)	E3 (Other Tests)
2011	37.67	0.00
2012	39.71	0.00
2013	41.87	13.62
2014	44.14	22.50
2015	46.53	26.31
2016	49.06	28.13
2017	51.72	30.14
2018	54.52	32.27
2019	57.48	34.55
2020	60.60	36.97
2021	62.85	39.54
2022	65.18	42.22
2023	67.61	45.10
2024	70.12	48.16
2025	72.72	51.45
2026	75.61	54.94
2027	78.60	58.73
2028	81.72	62.76
2029	84.95	67.09
2030	88.32	71.65
2031	91.67	73.08
2032	95.14	74.54

Sources: EPA and E3

[88] The EPA's social cost of carbon can be found at: https://www.whitehouse.gov/sites/default/files/omb/inforeg/social_cost_of_carbon_for_ria_2013_update.pdf.

[89] The team used the societal cost of carbon as an adder only for the societal cost test. This approach was agreed with the CPUC and included in the Work Plan for the project. Per the Work Plan, "Navigant will use the 2013 E3 Net Energy Metering avoided cost model for derivation of appropriate avoided costs. For societal avoided costs, Navigant will use an adder for societal cost of carbon based on the *2013 Interagency Working Group on Social Cost of Carbon* report or another published study that Navigant and the CPUC agree is appropriate." Navigant discussed and agreed on the approach with the CPUC on February 18, 2015.

E3's NEM Avoided Cost Model forecasts avoided costs for the following:

- Energy
- Line losses
- Ancillary services
- Emissions
- Generating capacity
- Transmission and distribution
- Renewable portfolio standards

By multiplying the hourly avoided costs by the hourly electric energy savings produced by the PV systems (for associated IOUs, climate zones, and installation years), Navigant determined the annual avoided costs over each system's 20-year lifetime. After considering PV production degradation of 1.25 percent per year and the appropriate discount rates, the team calculated the SASH and MASH levelized avoided costs over the 20-year PV system lifetime (see Table 2-14 and Table 2-15).

Table 2-14. SASH Levelized Avoided Costs ($/kWh)

TRC, PAC, and RIM Cost Tests

Install Year	PG&E	SCE	SDG&E	Wtd. Avg.
2011	0.12	0.12	0.13	0.12
2012	0.13	0.13	0.13	0.13
2013	0.13	0.13	0.14	0.13
Wtd. Avg.	**0.13**	**0.13**	**0.14**	**0.13**

SCT

Install Year	PG&E	SCE	SDG&E	Wtd. Avg.
2011	0.13	0.13	0.14	0.13
2012	0.14	0.14	0.14	0.14
2013	0.14	0.14	0.15	0.14
Wtd. Avg.	**0.14**	**0.14**	**0.15**	**0.14**

Source: Navigant Consulting, Inc.

Table 2-15. MASH Levelized Avoided Costs ($/kWh)

TRC, PAC, and RIM Cost Tests

Install Year	PG&E	SCE	SDG&E	Wtd. Avg.
2011	0.10	0.10	0.11	0.11
2012	0.11	0.11	0.11	0.11
2013	0.11	0.12	0.12	0.11
Wtd. Avg.	**0.11**	**0.11**	**0.11**	**0.11**

SCT

Install Year	PG&E	SCE	SDG&E	Wtd. Avg.
2011	0.11	0.11	0.12	0.12
2012	0.12	0.12	0.12	0.12
2013	0.12	0.13	0.13	0.12
Wtd. Avg.	**0.12**	**0.12**	**0.12**	**0.12**

Source: Navigant Consulting, Inc.

Although no differences existed in the hourly avoided costs for a given IOU and climate zone between SASH and MASH, the mix of sites installed in different climate zones and with different orientations (which produced different hourly PV energy profiles) led to different levelized avoided costs between the two programs.

2.3.3.3 CSI Incentives

Navigant used the CSI incentives from the Salesforce and PowerClerk databases and binned each project into a given installation year using the methods described in Section 2.2.1. The incentive totals in this report may differ slightly from those described in the *CSI Semi-Annual Expense Reports* because MASH PAs were not all consistent regarding which fields and dates from the database they used to bin projects for reporting purposes.

Table 2-16 provides the total SASH incentives, while Table 2-17 provides the SASH incentives as a percentage of equipment and installation costs. Although the SASH incentives did not fully cover the equipment and installation costs, GRID provided additional gap financing to cover nearly 100 percent of participants' out-of-pocket costs.[90] As such, inverter replacements (as well as any other service, maintenance, or operational costs) occurring beyond the 10-year equipment warranty are the only costs to participants in the SASH analysis.

Table 2-16. SASH Total Incentives ($)

Install Year	PG&E	SCE	SDG&E	Total
2011	8,030,959	5,842,614	1,750,160	15,623,733
2012	14,001,344	9,868,325	2,183,948	26,053,617
2013	6,082,557	8,444,470	3,025,228	17,552,254
Total	**28,114,860**	**24,155,409**	**6,959,336**	**59,229,605**

Source: Salesforce database

Table 2-17. SASH Incentives as a Percentage of Equipment and Installation Costs

Install Year	PG&E	SCE	SDG&E	Wtd. Avg.
2011	93%	96%	90%	94%
2012	97%	98%	92%	97%
2013	96%	99%	95%	97%
Wtd. Avg.	**96%**	**98%**	**93%**	**96%**

Source: Navigant analysis of Salesforce database

[90] The *Staff Proposal for the Implementation of Assembly Bill 217* states, "To date in the SASH program, systems have been installed cost-free for participating homeowners..." (http://www.cpuc.ca.gov/NR/rdonlyres/7D0007BD-E6F3-46EE-872F-DB7F00A328E5/0/AB217EnergyDivisionStaffProposalSASHandMASHJuly22014.pdf). Additionally, the SASH Q1 2014 Status Report comments, "In most instances GRID has aided in overcoming the gap financing obstacle for families by contributing the organization's own non-profit fundraising dollars toward covering the gap between the available incentive and the project's costs…" (http://www.cpuc.ca.gov/NR/rdonlyres/7D0007BD-E6F3-46EE-872F-DB7F00A328E5/0/AB217EnergyDivisionStaffProposalSASHandMASHJuly22014.pdf).

Table 2-18 provides the total MASH rebates, and Table 2-19 shows MASH incentives as a percentage of equipment and installation costs. Equipment and installation costs not covered by the MASH incentives are assumed to be paid by the system owners (rather than the tenants) in the cost-effectiveness analysis.

Table 2-18. MASH Total Incentives ($)

Install Year	PG&E	SCE	SDG&E	Total
2011	12,427,379	9,259,425	6,166,725	27,853,529
2012	8,013,452	15,687,357	2,401,816	26,102,625
2013	3,859,144	4,498,846	653,638	9,011,628
Total	**24,299,975**	**29,445,628**	**9,222,179**	**62,967,782**

Source: PowerClerk

Table 2-19. MASH Incentives as a Percentage of Equipment and Installation Costs

Install Year	PG&E	SCE	SDG&E	Wtd. Avg.
2011	53%	53%	65%	55%
2012	51%	56%	54%	55%
2013	42%	40%	43%	41%
Wtd. Avg.	**50%**	**52%**	**60%**	**52%**

Source: Navigant analysis of PowerClerk

2.3.3.4 *Administrative Costs*

The SASH administrative costs available to Navigant were totals rather than summaries by IOU. To allocate costs to each IOU, Navigant assigned administrative costs according to the relative number of projects installed in each IOU.[91]

For the MASH program, the steps to approximating administrative costs were as follows:

1. Determine the total number of installed arrays by IOU and installation year using the PAs' binning method[92].
2. Calculate an average administrative cost on a dollar-per-array basis for each IOU and installation year using the costs provided by the administrators and the number of installed arrays in each year and IOU.

[91] Using this method, the total administrative costs over 2011–2013 were allocated to each IOU as follows: 47 percent to PG&E, 40 percent to SCE, and 13 percent to SDG&E. The allocation in each year varies slightly based on the project distribution in that year. Comments on the first draft of this report revealed that GRID Alternatives' allocation of costs is as follows: 43.7 percent to PG&E, 46 percent to SCE, and 10.3 percent to SDG&E. The team ran the analysis using both allocations, and the differences in the results were negligible. Therefore, the findings in this report use the allocation described in this section.

[92] SCE's binning aligned well with the First Completed Date field, while PG&E's aligned with the First Pending Payment Date field from the PowerClerk database.

3. Assign the appropriate per-array cost to each array based on the administrators' binning method.
4. Re-bin the arrays using Navigant's binning method (for MASH, Navigant used the First Incentive Claim Review Request field from PowerClerk).
5. Sum the per-array administrative costs for all arrays falling in the newly binned installation year and IOU groupings.

Table 2-20 shows the SASH administrative costs, which Navigant allocated to each IOU.

Table 2-20. SASH Administrative Costs ($)

Install Year	PG&E	SCE	SDG&E	Total
2011	1,081,388	761,072	240,878	2,083,338
2012	1,203,920	901,614	233,359	2,338,893
2013	886,792	1,069,635	393,114	2,349,541
Total	3,172,100	2,732,321	867,351	6,771,772

Source: Navigant analysis of PA data

Table 2-21 provides the MASH administrative costs, which Navigant adjusted to account for SCE's and PG&E's different binning methods.[93] For this reason, the SCE and PG&E administrative costs for MASH will be slightly different from the values appearing in the *CSI Semi-Annual Expense Reports*.

Table 2-21. MASH Administrative Costs ($)

Install Year	PG&E	SCE	SDG&E	Total
2011	515,592	307,791	171,090	994,473
2012	233,407	355,482	158,460	747,350
2013	311,491	155,677	63,409	530,577
Total	1,060,490	818,951	392,959	2,272,400

Source: Navigant analysis of PA data

2.3.3.5 Metering Costs

Recurring metering costs only appear in the retail rate tariffs applicable to SCE VNM customers,[94] so Navigant only applied metering costs to those customers. Per the posted tariff structures, SCE VNM customers incur a $0.836/meter-day charge. The study escalated those metering costs over time using a two percent per year inflation rate.[95] Navigant did not treat these metering charges as a monetary benefit

[93] Navigant used SDG&E's MASH administrative costs as provided because they were binned similarly to Navigant's method outlined in Section 2.1.1. For SCE's and PG&E's MASH administrative costs, Navigant approximated the administrative costs based on Navigant's binning method.

[94] Confirmed by PAs on March 18, 2015 by email.

[95] Per the GS-1 rate schedule: https://www.sce.com/NR/sc3/tm2/pdf/ce74-12.pdf.

to SCE in the cost tests because the project team assumed SCE was applying the charge as a means to recover costs related to the VNM tracking/billing infrastructure and administration.

2.3.3.6 *Participant Ownership Costs*

The Salesforce and PowerClerk databases provided the upfront system equipment and installation price. The SASH equipment and installation prices on a $/kW-DC (STC) basis showed a declining trend for all IOUs between the years 2011 and 2013, as is shown in Table 2-22. The MASH equipment and installation costs did not show a declining trend over time, on average, as is shown in Table 2-23, and were actually higher than the SASH costs, on average. The higher MASH costs are interesting considering that the average MASH project size was 67.3 kW-DC (PTC) compared with SASH's average project size of 3.1 kW-AC (CEC). Typically, equipment and installation costs decline as the project size increases.

Table 2-22. SASH Average Equipment and Installation Prices ($/kW-DC [STC])

Install Year	PG&E	SCE	SDG&E	Wtd. Avg.
2011	5,864	5,846	6,071	5,881
2012	5,526	5,388	5,829	5,498
2013	5,012	5,073	5,287	5,088
Wtd. Avg.	**5,498**	**5,377**	**5,642**	**5,465**

Source: Navigant analysis of Salesforce database

Table 2-23. MASH Average Equipment and Installation Prices ($/kW-DC [STC])

Install Year	PG&E	SCE	SDG&E	Wtd. Avg.
2011	5,743	6,493	5,366	5,903
2012	5,598	5,292	5,581	5,415
2013	4,848	6,575	5,233	5,643
Wtd. Avg.	**5,505**	**5,857**	**5,413**	**5,653**

Source: Navigant analysis of PowerClerk database

Navigant ran the E3 CSI Single-Installation Cost-Effectiveness Tool to determine ownership costs over the 20-year PV system lifetime.[96] The E3 tool accounts for the following:

- Financing costs, including TPO structures (i.e., power purchase agreements)
- State and federal taxes, including Investment Tax Credits and Modified Accelerated Cost Recovery System (MACRS) depreciation
- Insurance
- Operations and maintenance (O&M) costs
- Inverter replacement costs

[96] https://www.ethree.com/documents/CSI/CSI%20Report_Complete_E3_Final.pdf

For each installation group, Navigant input the average project characteristics in terms of system size, equipment and installation costs, rebates, and annual energy production into E3's Cost-Effectiveness Tool. Navigant also modified the PV system degradation rate to 1.25 percent per year, and set the renewable energy credits and metering costs to zero (SCE metering costs for VNM customers were treated outside of the E3 tool). All other assumptions related to the bulleted items above defaulted to E3's assumptions, which are included in Appendix C.

The E3 Cost-Effectiveness Tool produces a pro-forma for cash flows over the 20-year system life, which allowed Navigant to find the net present value (NPV) of ownership costs over the system lifetime. The NPV of ownership costs were then divided by the upfront installation costs to find a fixed charge rate, as expressed in Equation 2-4 and shown in Table 2-24. Knowing the fixed charge rate for each installation group allowed Navigant to scale each group's total equipment and installation price (rather than average prices) to reflect lifetime ownership costs[97]. The project team used these lifetime ownership costs in Navigant's cost-effectiveness tool rather than using the total upfront equipment and installation costs. Navigant scaled the equipment and installation prices for each installation group to capture the unique financing and tax characteristics of each group.

Equation 2-4. Fixed Charge Rate[98]

$$FCR = \frac{NPV(Equity + Debt + O\&M + Insurance + Inverter + Taxes)}{Equipment + Installation}$$

Table 2-24. MASH Average Fixed Charge Rates (unitless)

Install Year	PG&E	SCE	SDG&E	Wtd. Avg.
2011	0.76	0.80	0.77	0.78
2012	0.82	0.73	0.75	0.76
2013	0.77	0.69	0.82	0.73
Wtd. Avg.	**0.78**	**0.74**	**0.77**	**0.76**

Source: Navigant Consulting, Inc.

A fixed charge rate less than 1.0 indicates that the average NPV of ownership costs is less than the average upfront equipment and installation price. This occurs when favorable financing structures and tax benefits, such as the Federal Investment Tax Credit and accelerated depreciation, reduce the effective cost of the system. On average, MASH investors could expect the present value of all ownership over the system lifetime to be 18 to 31 percent[99] lower than the upfront invoice price of the installed system. For the given study period commercial entities and third-party organizations were able to claim the 30 percent Federal Investment Tax Credit and MACRS accelerated depreciation. Navigant notes that government and non-profit organizations did not receive any tax benefits, but they only account for a small percentage of the MASH installed PV capacity. Thus, their impact on these average fixed charge rates by IOU and installation year is minimal.

[97] Lifetime ownership costs are equal to the system price times fixed charge rate.
[98] Only inverter replacement costs are applicable to SASH. Therefore, the fixed charge rate does not apply to SASH.
[99] This range is the minimum and maximum for 2011, 2012, and 2013.

The Federal Investment Tax Credit and MACRS accelerated depreciation were not applicable for SASH because SASH participants made no investment in the system. Only inverter replacement costs were applicable to SASH participants, and GRID ensures that inverter warranties are valid for 10 years. After warranty expiration, however, the SASH participants are responsible for inverter replacement costs. This study assumed all SASH participants would incur one inverter replacement cost (and any other associated O&M costs) during the system lifetime and that inverter would function for the remaining 10 years of the PV system's life. Table 2-25 shows the average present value of inverter replacements and maintenance, which are the only costs incurred by the SASH participants in this analysis.[100]

Table 2-25. SASH Average Present Value of Inverter Replacements ($/Replacement)

Install Year	PG&E	SCE	SDG&E	Wtd. Avg.
2011	845	855	829	847
2012	887	848	715	855
2013	717	792	774	761
Wtd. Avg.	**831**	**829**	**767**	**822**

Source: Navigant Consulting, Inc.

2.3.3.7 Participant and Utility NEBs

The cost-benefit analysis calculated cost tests under two scenarios. The first scenario excludes NEBs while the second scenario includes them. For information on how NEBs were calculated, see Section 2.3.5.

2.3.4 Other Key Inputs

Other key inputs to the cost-benefit analysis include discount rates and energy savings hourly profiles.

2.3.4.1 Discount Rates

This study used different discount rates, as shown in Table 2-26, for each of the various stakeholder perspectives and cost tests. The IOU-specific discount rates are the IOU's weighted average cost of capital from D.12-12-034.[101] The remaining discount rates come from E3's CSI Single-Installation Cost-Effectiveness Tool.[102] Because E3 released the tool in 2010, Navigant decreased the SCT discount rate to reflect changes in the Treasury Rate index, which reflects a societal cost of capital. After looking at

[100] Navigant applied participant discount rates for residential customer types to determine the present values of inverter replacement costs expected to occur 10 years after the initial installation date. The E3 model assumes participants can obtain a 10-year financing term for the inverters.
[101] On 11/13/2014, Shannon O'Rourke of the CPUC advised Navigant to use the weighted average cost of capital approved for each IOU in CPUC Decision 12-12-034. The team confirmed with the CPUC that the weighted average cost of capitals in the decision were before-tax rates (confirmed via email with Elizabeth Curran on 9/11/2015). The team adjusted the before-tax rates for tax and used the after-tax rates in the analysis.
[102] The E3 CSI Single-Installation Cost-Effectiveness Tool is accessible from: https://ethree.com/public_projects/cpuc.php.

changes in the prime rate and relying on Navigant's experience with market trends, the project team determined that the participant rates used in the E3 tool were still valid.

Table 2-26. Discount Rates by Cost Test and Stakeholder

Cost Test	Category	Nominal Discount Rate
TRC/PAC/RIM	PG&E	6.93%
	SCE	6.87%
	SDG&E	6.80%
PCT	Residential	4.36%
	Commercial	8.25%
	Government	4.21%
	Non-Profit	8.25%
	Third-Party-Owned	8.25%
SCT	N/A	4.10%

Sources: CPUC, E3

2.3.4.2 *Energy Savings Hourly Profiles*

Section 3.3.2 describes the first-year energy savings hourly profiles that Navigant imported into its Cost-Effectiveness Calculator. For all periods after the installation year, Navigant applied a 1.25 percent per year production degradation factor to the first-year profiles. The degradation factor comes from the E3 Avoided Cost tool and includes physical degradation of system components (e.g., declining efficiency of modules [semiconductor material], corrosion of wiring connections, etc.).[103]

2.3.5 Non-Energy Benefits

Navigant adapted the CPUC's Low-Income Public Purpose Test (LIPPT), an Excel-based model that estimates non-energy benefits (NEBs) for low-income energy efficiency programs, to determine the equivalent value of the NEBs achieved under the SASH and MASH programs. This section describes Navigant's approach to estimating NEBs for the SASH and MASH programs using the LIPPT framework.

2.3.5.1 *Background*

The developers of the LIPPT framework based the model on the premise that weatherization programs generate benefits beyond what are typically factored into utility cost-effectiveness tests. These other benefits are NEBs. The LIPPT model calculates NEBs from three perspectives: the utility perspective, the participant perspective, and the societal perspective.

[103] E3 CSI/SGIP Avoided Cost Calculator, dated April 7, 2015.

Table 2-27 shows a list of all of the potential NEBs considered in the LIPPT model.

Since many of the low-income solar PV benefits align with a per-participant approach to assessing energy efficiency NEBs using the LIPPT model, Navigant adapted the CPUC's approach to evaluating NEBs for low-income energy efficiency programs in order to provide a sense of the equivalent value of the NEBs achieved under the SASH and MASH programs. While developers did not design the LIPPT with distributed generation programs in mind, it provides a reasonable framework and starting point for developing a distributed generation-specific approach while growing the collective body of knowledge about NEB evaluation.

This quantitative analysis provides an initial proxy value for solar-related NEBs upon which future evaluations can build. Additionally, Navigant did not intend to align and compare the items Navigant investigates as NEBs with the CPUC's goals for the SASH and MASH programs. A more robust assessment of distributed generation-specific NEBs should include a bottom-up analysis of the estimated incremental benefits (and avoided or incremental costs) of those non-energy factors, but such an assessment is beyond the scope of this evaluation.

The following sections describe Navigant's approach to calculating solar-related NEBs in detail.

2.3.5.2 NEB Calculation Approach

This section describes the first two steps in the NEB calculation: assess which NEBs from the LIPPT model apply to solar and convert energy efficiency NEBs to solar NEBs.

Step 1: Examine the original assumptions and calculations for each NEB in the LIPPT model to determine which benefits reasonably apply to a solar program. Navigant determined which NEBs apply to low-income solar PV programs such as SASH and MASH.

Table 2-27 shows all of the NEBs considered in the LIPPT and indicates with an asterisk the NEBs that apply to low-income solar PV programs

Table 2-27. NEBs Considered in LIPPT

Beneficiary	Non-Energy Benefit
Utility	Reduced carrying cost on arrearages (interest)[104]*
Utility	Lower bad debt written off*
Utility	Fewer shutoffs*
Utility	Fewer reconnects*
Utility	Fewer notices*
Utility	Fewer customer calls*
Utility	Lower collection costs*
Utility	Reduction in emergency gas service calls
Utility	Utility health and safety - insurance savings only
Utility	Transmission and/or distribution savings (distribution only)
Utility	Utility rate subsidy avoided (CARE) payments*
Societal	Economic impact (direct and indirect employment)**
Societal	Emissions/environmental**
Societal	Health and safety equipment (CO and Other health and safety)
Societal	Water and wastewater (avoided)
Participant	Water/sewer savings
Participant	Fewer shutoffs*
Participant	Fewer calls to the utility*
Participant	Fewer reconnects*
Participant	Property value benefits*
Participant	Fewer fires
Participant	Indoor air quality (CO-related)
Participant	Moving costs/mobility*
Participant	Fewer illnesses and lost days from work/school
Participant	Reduced transactions costs (limited measures)
Participant	Net household benefits from comfort, noise
Participant	Net household benefits from additional hardship benefits*

*Indicates NEBs that apply to low-income solar PV programs.
**Indicates NEBs that could apply to low-income solar PV programs but were not considered in this analysis because the LIPPT report conservatively estimated the value to be zero in order to avoid double counting with other avoided cost values.
Source: Navigant Consulting, Inc.

[104] Arrearages are unpaid/overdue payments; carrying cost is the interest the IOU would need to pay on that unpaid/overdue amount from their customers.

For the MASH program, energy bill savings only accrue to tenants under VNM arrangements, according to the allocation of credits specified in the building owner's interconnection application. While non-VNM (i.e., NEM) tenants theoretically can benefit from systems that offset common area load in other ways, NEBs were only calculated for MASH VNM tenants because the NEBs identified in

Table 2-27 result from a participant's energy bill savings and an increased ability to pay the energy bills in full and on time. Therefore, the NEBs discussed in this report apply to SASH participants and MASH VNM tenants.

Step 2: Convert LIPPT values for energy efficiency weatherization programs to NEBs for solar based on estimated annual bill savings for SASH and MASH systems directed to serve tenant load. At the end of the year, utilities write off some of their bad debt when consumers do not pay their utility bills. Weatherization programs generate energy savings that lead to utility bill savings, potentially making energy bills more manageable for participants. As a result, the utility may be able to reduce the bad debt associated with these customers.

This program-induced benefit (the program-induced percent reduction in bad debt write-offs per participant household per year) is a key metric estimated in the LIPPT model. For example, if the utility writes off $5 in bad debt per low-income household per year and the program-induced percent reduction in bad debt write-offs is 20 percent, then the NEB of the weatherization program to the utility is $1 for that participant household. Equation 2-5 describes this example.

Equation 2-5. Bad Debt Written Off Example

$$\text{NEB: Bad Debt Written Off} = \text{Avg Bad Debt Per Customer x Program Induced \% Reduction in Bad Debt Write} - \text{offs}$$

$$\text{NEB: Bad Debt Written Off } = \$5 \text{ x } 20\% = \$1.00$$

For all benefits that apply to low-income solar PV programs, Navigant adjusted the LIPPT model's inputs to account for price inflation over time using a Consumer Price Index factor.[105] In addition, Navigant used scaling factors to account for the difference in program impacts due to increased bill savings for solar programs over energy efficiency programs. The scaling factor is the ratio of the average energy savings from a low-income energy efficiency program to the average savings from a low-income solar program.

The weatherization program impacts represent a typical low-income weatherization program where energy savings translate into average energy bill savings.[106] However, program benefits do not accrue to all programs equally. Programs that generate more energy savings per household lead to higher bill savings and likely increase the NEBs to the utility. Similarly, since low-income solar programs can lead to significant bill savings for low-income participants, it is reasonable to assume that the NEBs of solar programs are greater than the benefits of energy efficiency programs .[107] To account for this difference, Navigant used a scaling factor to compare the average energy bill savings from a low-income solar

[105] U.S. Department of Labor, Bureau of Labor Statistics Consumer Price Index: http://www.bls.gov/cpi/

[106] NEBs derived in the LIPPT model are based on secondary data, literature review, primary data from California utilities, and assumptions based on weatherization program design.

[107] Some tenants in MASH projects do not realize any energy bill savings, depending on whether their property is participating in MASH under NEM or VNM.

program, such as SASH, to bill savings from a low-income weatherization program. Navigant then multiplied the scaling factor by the program-induced benefit for an energy efficiency program to obtain an estimate of the NEBs for a low-income solar program.

To calculate a scaling factor for SASH and MASH, Navigant divided each utility's average annual bill savings for SASH/MASH participants by the annual weatherization program participant bill savings presented in the LIPPT model.[108] Equation 2-6 is an example.

Equation 2-6. Scaling Factor

Average annual SASH participant bill savings = $323.00
Annual weatherization program participant bill savings = $175.00
Scaling factor = $323/$175=1.85

$$\text{Scaling Factor} = \frac{\text{Average annual SASH participant bill savings}}{\text{Annual weatherization program participant bill savings}}$$

The team then applied the scaling factor to the NEB calculations, such as the following equation for bad debt written off.

$$\text{NEB: Bad Debt Written Off} = \text{Avg Bad Debt Per Customer x Program Induced \% Reduction in Bad Debt Write} - \text{offs x Scaling Factor}$$

Therefore,

$$\text{NEB: Bad Debt Written Off} = \$5.00 \text{ x } 20\% \text{ x } 1.85 = \$1.85$$

2.3.5.3 Discussion of Specific NEB Issues and Decisions

This section presents a discussion of categories that warranted additional research before completing the analysis of NEBs, including benefits from health and safety measures and property value benefits.

Health and Safety Measures

California statewide code requires smoke alarms and carbon monoxide (CO) monitors in all homes, not only those installing solar PV. However, enforcement across California is inconsistent: when pulling a permit to install solar, some jurisdictions check to see if smoke alarms and CO monitors are installed, and others do not. In-depth interviews with SASH subcontractors suggest that roughly half of single-family home solar PV projects are installed in jurisdictions that require fire alarms and CO detectors. The permitting process required to install PV may result in some participants installing smoke alarms and CO detectors that did not previously have them, which would result in increased home safety. However, further analysis is required in order to determine the extent of health and safety benefits resulting from

[108] The average annual savings in the LIPPT model was $175 per participant per year. Navigant adjusted these to account for inflation by scaling from 2001 dollars to 2014 dollars using the Consumer Price Index.

the installation of solar PV. Consequently, Navigant used a conservative estimate and assumed the health and safety benefit associated with SASH and MASH programs to be zero.

Property Value Benefits

California homes with solar PV may sell for a premium over similar homes without solar PV, creating property value benefits to SASH participants. However, participating SASH homes are subject to resale restrictions that effectively prevent the homeowner from realizing a significant increase in their home value from the installation of a PV system. Exact specifications of these resale restrictions vary depending on how the home is classified as affordable housing.[109] Navigant assumes that nearly all homes participating in SASH likely fall under some type of deed or resale restriction.[110] However, it is out of scope to determine the average maximum allowable increase in home value that deed-restricted homes can capture due to variations across the different resale restriction agreement types and differences from jurisdiction to jurisdiction. Therefore, Navigant used a conservative estimate and assumed that the average property value benefit is zero. Further analysis is needed in order to refine this estimate.[111]

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[109] For example, paragraph (2) of subdivision (c) of Section 65915 of the Government Code states that "the local government's proportionate share of appreciation shall be equal to the ratio of the local government's initial subsidy to the fair market value of the home at the time of initial sale.."

[110] One of the SASH eligibility requirements is that participants live in a home defined as "affordable housing." Affordable housing is defined by California Public Utilities Code 2852 and is generally defined as a home that cannot be sold without restrictions on the real estate market. See more at: http://www.gridalternatives.org/learn/sash/sash-eligibility-requirements#sthash.kVsmVII3.dpuf

[111] If the value of a SASH solar PV system is greater than the maximum allowed home value increase, Navigant could assume that the average maximum allowed home value increase is equal to a participant's property value benefit in an NEB calculation. Navigant could calculate the property value benefit as the average equity sharing homeowner percentage multiplied by the average California low-income home value.

3 SASH Findings

The evaluation of the SASH program shows that the PV systems are installed and operating as intended and that the program is only cost-effective from the PCT perspective.

This section presents the SASH findings in a similar structure to the methodology section and includes the following topics:

- Section 3.1—Summary of Installed SASH Projects
- Section 3.2—SASH Desk Review and Field Verification Findings
- Section 3.3—SASH Impact Analysis Findings
- Section 3.4—SASH Cost-Benefit Analysis Findings

3.1 SUMMARY OF INSTALLED SASH PROJECTS

The SASH program installed 3,164 projects between 2011 and 2013, providing 9,731 kW-AC (CEC) of interconnected capacity. For maps showing the geographic distribution of installed projects, see the Market and Program Administrator Assessment.[112] The rate of new system installations increased through 2012, and began tapering somewhat in 2013. Table 3-1 shows new interconnected capacity by

[112] Navigant Consulting, Inc. "California Solar Initiative—Biennial Evaluation Studies for the Single-Family Affordable Solar Homes (SASH) and Multifamily Affordable Solar Housing (MASH) Low-Income Programs: Market and Program Administrator Assessment, Program Years 2011–2013." Prepared for the California Public Utilities Commission.

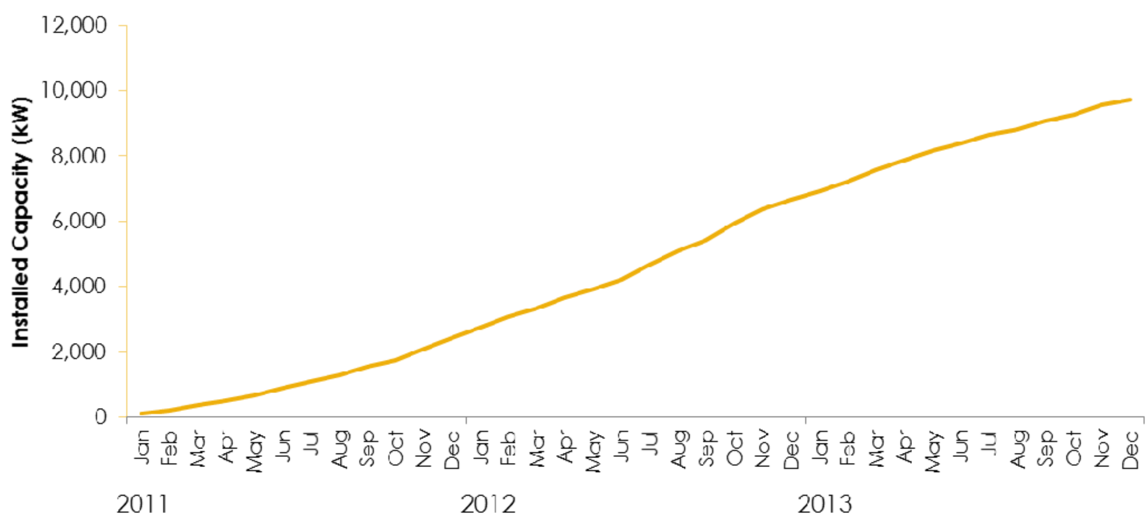
quarter from the beginning of 2011 to the end of 2013. Figure 3-1 shows the same data graphed on a monthly basis since the beginning of 2011.

Table 3-1. SASH New Interconnected Capacity by Quarter[113]

Year	Quarter	New Capacity Since Previous Quarter	Cumulative Number of Projects	Cumulative Capacity (kW-AC [CEC])
2011	1	378	138	378
	2	520	306	898
	3	643	529	1,541
	4	889	813	2,430
2012	1	923	1,099	3,353
	2	878	1,372	4,231
	3	1,205	1,742	5,436
	4	1,228	2,136	6,664
2013	1	896	2,420	7,560
	2	845	2,699	8,405
	3	660	2,926	9,065
	4	666	3,164	9,731

Source: Navigant analysis of Salesforce database

Figure 3-1. SASH New Interconnected Capacity for 2011-2013 (kW-AC [CEC])



Note: Chart does not include capacity installed/interconnected before 2011.

Source: Navigant analysis of Salesforce database

[113] Interconnected capacity is in terms of PTC rating.

3.2 SASH DESK REVIEW AND FIELD VERIFICATION FINDINGS

The goal of the field verification was to verify the installed capacity and system characteristics for model input. In addition to the field verification, Navigant completed a desk review for a sample of projects. This section presents the findings from the desk review and field verification. The desk review found a number of minor record-keeping discrepancies, and the field verification uncovered some issues related to measuring and documenting PV system characteristics. Overall, these had little effect on the design factor verification rate (DFVR). This section is organized as follows:

- Section 3.2.1—Desk Review Findings
- Section 3.2.2—Field Verification Findings

3.2.1 Desk Review Findings

Navigant encountered a number of issues while completing the desk review, as outlined below. The overall impact of the issues was minor.

- **Version control:** The application and inspection process sometimes creates multiple versions of EPBB models, one-line diagrams, and inspection worksheets. This could occur if there was a change from the pre-install EPBB configuration that happened during construction or if the post-install third-party inspection uncovered discrepancies. The team found the PA does minimal tracking of the version control of the documents. For example, the assumptions for a given site (e.g., shading factors, tilt, and azimuth) documented in the third-party inspection sheet provided to the evaluation team by GRID Alternatives frequently do not match those documented in the third-party inspection sheet uploaded onto the Salesforce tracking database. Lack of version control increases the likelihood of clerical errors and reduces the transparency of the process.
- **Clerical errors:** Every parameter tracked in the Salesforce database should be traceable to the underlying third-party verified documentation. However, a significant number of sites in the SASH data system have parameters that do not match third-party verified inspection worksheets or the original EPBB calculator printouts. For example, the desk review revealed that six of 10 randomly sampled SASH sites had clerical errors in DF between the EPBB calculator printouts and the Salesforce database. In other words, the DF listed in the Salesforce database did not match the design factor documented in the latest EPBB printouts for 60 percent of the field-sampled sites. The largest of these discrepancies was one site that had an EPBB-listed DF of 98.8 percent versus the tracking database-recorded DF of 90.6 percent. Most of the errors were small and with no consistent direction. When averaged over the 10 sites, these kinds of discrepancies resulted in a clerical error of only 1.2 percent. See Section 2.2.3 for the full details of the DF verification calculation.
- **Lack of a clear paper trail:** The project development process should be clearly understandable to an auditor, evaluator, or regulator reviewing the project database and records. Changes made to the system between the original design, installed system, and results of the third-party inspection should all be included in the project record in the Salesforce database and be easily traceable.

Navigant also encountered numerous issues with data quality and accessibility. Appendix A contains several data-related recommendations as well as a memo Navigant sent to the CPUC on January 15, 2015 outlining issues accessing evaluation data.

3.2.2 Field Verification Findings

Navigant's field verification visits demonstrated that systems are generally operating as expected and the field verification team did not encounter any major issues affecting PV performance. However, some issues were encountered during the field verifications. For example, one out of the five SASH sites in the field sample did not have the third-party inspection worksheet available for review. In addition, while the SASH PV installations generally matched what was listed in the program tracking database, Navigant's field inspectors did uncover two minor issues—incorrect array grouping and incorrect tilt and azimuth values. More details on the incorrect array grouping and incorrect tilt and azimuth issues are provided below.

Incorrect Array Grouping

Navigant evaluated each of the sites in the field visits to verify that SASH installers correctly handled documentation of array grouping. According to the CSI System Inspection Protocol:[114]

> *When an installation is split into sections having different tilt angles or different azimuth orientations, a separate Field Inspection Worksheet printout calculation must be submitted for each section of the array.*

Navigant defines a group of panels the same way the CSI Handbook refers to a section: a group is one or more PV module(s) sharing the same orientation (i.e., identical tilt and azimuth angles).[115] The assumption is that because these modules face the same direction, they can be treated as a single unit from an energy production standpoint. Navigant found one site out of five in which the number of panels split between two groups was incorrect—one panel was included with one group when it should have been included with the other group. The same site also had an azimuth discrepancy of 180 degrees (i.e., one of the array groups was listed as east facing when it was west facing). A third-party inspector did not inspect this site. The correction resulted in a reduction of the site's DF from 97.2 percent to 94.6 percent.

Incorrect Tilt and Azimuth

Navigant field crews found one array where the measured tilt differed from the value in the tracking database by three degrees or more. Navigant also found five cases where measured azimuth differed from reported values by more than five degrees. Two of the azimuth discrepancies were off by more than 10 degrees, potentially signifying that magnetic bearings were not consistently being converted to true bearings (the difference between true north and magnetic north, called magnetic declination, ranges

[114] http://www.pge.com/includes/docs/word_xls/shared/solar/csi/form_csifieldinsepection.xls.

[115] Note that Navigant defines array differently from the CSI Handbook when describing PV systems. In this report, array refers to a group of panels that is modeled independently from other groups of panels. A single site may have multiple arrays even if it only has a single inverter.

from 12 degrees to 16 degrees in California depending on location). For more information on correctly accounting for magnetic declination, see the field protocol in Appendix B.

3.3 SASH IMPACT ANALYSIS FINDINGS

The team completed the impact analysis of SASH projects to meet the following objectives. This section details the findings of each of these objectives.

- Produce estimates of the following parameters:
  - Section 3.3.1—Design Factor Verification Rate (unitless)
  - Section 3.3.2—Energy production (MWh)
  - Section 3.3.3—Capacity factor (unitless)
  - Section 3.3.4—Demand reduction (CAISO peak/IOU peak, kW-AC [meter])
  - Section 3.3.5—Greenhouse gas emissions reduction (tons CO_2)
  - Section 3.3.6—Assess bill impacts for participating customers ($ per customer)

3.3.1 Design Factor Verification Rate

The primary result from the field verification and associated desk review is the DFVR. Consistent with the 2009–2010 SASH evaluation, DFVR was very close to 1.0.[116] The analysis meets the 90/30 confidence/precision target. Table 3-2 shows the results of the DFVR calculation.

Table 3-2. SASH DFVR

Parameter	Design Factor Verification Rate
Mean	1.021
Standard deviation	0.043
Standard error	0.019
Z value at 90% confidence interval (4 degrees of freedom)	2.132
Relative precision at 90% confidence interval	4.1%

Source: Navigant Consulting, Inc.

[116] Navigant Consulting, Inc. California Solar Initiative *Low- Income Solar Program Evaluation: Program Impacts and Cost-Benefit Report Program Years 2009-2010.* Prepared for the California Public Utilities Commission.

Another metric Navigant calculated was the clerical error realization rate (CERR), which tracks the effects of errors entering array characteristics and EPBB calculator results into the database. Table 3-3 shows the results of calculating the CERR.

Table 3-3. SASH CERR

Parameter	Clerical Error Realization Rate
Mean	1.012
Standard deviation	0.049
Standard error	0.022
Z value at 90% confidence interval (4 degrees of freedom)	2.132
Relative precision at 90% confidence interval	4.7%

Source: Navigant Consulting, Inc.

While the CERR can be affected by any number of system characteristics being transcribed in the database incorrectly (resulting in a different hypothetical EPBB output), for SASH it appears that the largest source of clerical error was simply misrecorded DF values. With six of 10 sampled sites showing disagreement between the documented modified DF (via EPBB and FIWS forms) and recorded modified DF in Salesforce, Navigant calculated a DF-specific sample clerical error of 1.2 percent for the SASH sites, represented as a 1.012 CERR.

3.3.2 Energy Production

Understanding a program's energy impacts is important because it gives a sense for the scale of the program and a metric for comparison with other programs. Navigant defines energy impacts in this evaluation as the annual electrical energy (MWh) produced by program-incentivized PV arrays. For energy impacts, Navigant reported energy production using both the actual year 8,760 production shapes and typical 8,760 production shapes using TMY data (referred to as typical year). Actual year gives a retrospective estimate of the impacts in 2011–2013, while the typical year impacts are more representative of what the systems are likely to produce yearly in the future. The findings of impacts from both views, actual year and typical year, are presented in this section.

3.3.2.1 Actual Year Energy Impacts

The SASH PV arrays installed during 2011–2013 generated approximately 23,824 MWh of electricity through the end of 2013. Table 3-4 and Table 3-5 show the results of the energy impact calculations modeled using actual historic conditions. For actual year impacts, Navigant used actual historical weather and discarded any PV production modeled before each system's interconnection date. These tables present the energy impacts as seen by the electric grid—i.e., the 2011 energy production total contains energy produced in 2011 only by those sites installed throughout 2011, while 2013 energy production includes energy produced in 2013 by systems installed in 2011, 2012, and 2013. The total refers to the total energy production attributable to SASH from 2011–2013 and does not include production from before each site's interconnect date.

Table 3-4. Actual Year Energy Impacts of SASH Projects

Install Year	Total Energy (MWh)
2011	1,609
2012	7,475
2013	14,740
Total	**23,824**

Source: Navigant Consulting, Inc.

Table 3-5. Actual Year Energy Impacts of Installed SASH Projects by Year and Quarter (MWh)

Year	IOU	Q1 MWh	Q2 MWh	Q3 MWh	Q4 MWh	Total
2011	PG&E	33	194	322	299	**847**
	SCE	17	96	225	222	**560**
	SDG&E	12	44	72	73	**202**
2012	PG&E	528	1,110	1,316	846	**3,799**
	SCE	428	841	953	702	**2,924**
	SDG&E	124	202	242	184	**752**
2013	PG&E	1,334	2,293	2,250	1,415	**7,292**
	SCE	1,045	1,814	1,769	1,240	**5,868**
	SDG&E	276	445	486	373	**1,580**

Source: Navigant Consulting, Inc.

3.3.2.2 Typical Year Energy Impacts

Assuming typical weather conditions, the 3,164 SASH projects installed in 2011–2013 will produce about 17,536 MWh of electricity each year. Table 3-6 shows the typical year impacts by install year, while Table 3-7 shows the same data broken down by IOU and quarter. Note that the total typical year production shown in Table 3-6 is substantially lower than the total actual year production presented in Table 3-4. This is because Table 3-6's total represents the sum of three single years' typical energy production, while Table 3-4's total refers to total production from systems installed over three years summed over that three-year period.

Table 3-6. Typical Year Energy Impacts of SASH Projects Online by the End of the Year

Install Year	MWh
2011	4,341
2012	7,595
2013	5,600
Total	**17,536**

Source: Navigant Consulting, Inc.

Table 3-7. Typical Year Energy Impacts of Installed SASH Projects by Year and Quarter (MWh)

Year	IOU	Q1 MWh	Q2 MWh	Q3 MWh	Q4 MWh	Total
2011	PG&E	422	712	680	385	**2,199**
	SCE	340	507	477	307	**1,632**
	SDG&E	109	151	151	98	**509**
2012	PG&E	756	1,297	1,229	685	**3,967**
	SCE	615	929	871	557	**2,971**
	SDG&E	140	196	195	127	**657**
2013	PG&E	360	617	589	329	**1,895**
	SCE	558	841	792	504	**2,695**
	SDG&E	215	300	301	194	**1,010**

Source: Navigant Consulting, Inc.

3.3.3 Capacity Factor

Capacity factor (CF) is a ratio of the actual output of a system during a specified time period to the theoretical rated capacity of that system during the same time period. CF is a metric that is used in the power industry to describe the reliability of power plants. For PV generation, it can be used to compare efficacy and available solar resources across one or many PV systems.

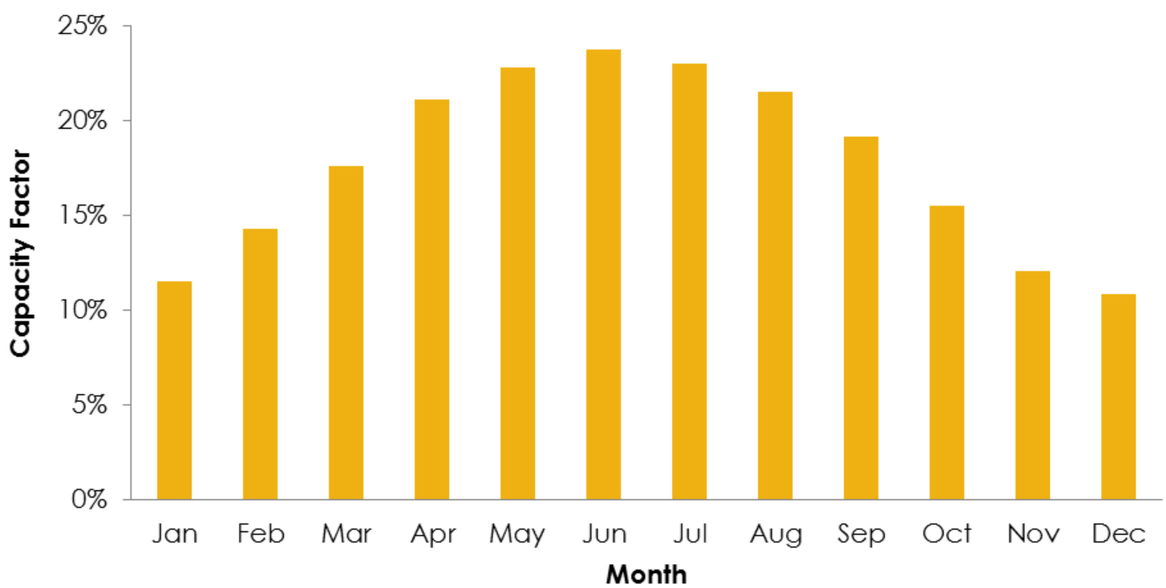
Table 3-8 summarizes the program-wide annual CF by year. The annual CF varied each year and ranged from 17.5 percent to 18.1 percent. Figure 3-2 shows the average CF by month for all projects installed in 2011–2013. Differences in CF over time are primarily attributable to changes in weather or, more specifically, the amount of incident solar radiation on the PV system. Factors like solar geometry, shading, and equipment efficiency are installation-specific factors, which influence CFs. For a table showing CF by IOU, refer to Appendix D.

Table 3-8. SASH Program-Wide Capacity Factors for 2011-2013

Install Year	Capacity Factor
2011	17.5%
2012	17.8%
2013	18.1%

Source: Navigant Consulting, Inc.

Figure 3-2. SASH Capacity Factor by Month Averaged over 2011-2013



Source: Navigant Consulting, Inc.

3.3.4 Demand Reduction

Navigant calculated SASH demand reduction impacts during the CAISO peak hour by summing the modeled (actual weather) kWh energy production during those hours by IOU and year. Peak hour refers to the hour during which the actual system-wide peak occurred according to CAISO. For peak demand impacts, Navigant used actual weather and discarded any PV production modeled before each system's interconnect date (Navigant refers to this case as actual year).

Table 3-9 shows the number of sites online by the time of the CAISO system peak demand in each year (for details see Section 2.2.7). In addition, the table shows the installed capacity by the time of the peak demand reduction. At the time of the CAISO peak, Navigant models estimated a peak demand reduction of about 587 kW-AC (meter) in 2011. In 2012, the 1,566 systems installed before the date of

CAISO peak were responsible for an approximate 2,919 kW-AC (meter) peak reduction. By the time of the 2013 CAISO peak, 2,699 sites were contributing to peak demand reductions for a total of 4,265 kW-AC (meter). For utility-specific peak demand reductions, see Appendix D.

Table 3-9. CAISO Peak Demand Reductions Attributable to Interconnected SASH Systems

Year	# of Sites Online	Installed Capacity (kW-AC [CEC])	Demand Reduction (kW-AC [meter])	Peak Capacity Factor
2011	466	1,346	587	44%
2012	1,566	4,849	2,919	60%
2013	2,699[117]	8,405	4,625	55%

Source: Navigant Consulting, Inc.

In addition, Table 3-9 shows the peak capacity factor, which is the ratio of peak power production to the total CEC-AC rating of the PV arrays installed and interconnected before the date of the peak event. It is a metric of how favorable conditions were for solar power production during the peak time and accounts for factors such as geographic distribution of the arrays, tilt, azimuth, shading, cloud cover, and time of day. Peak capacity factors ranged from 44 percent to 60 percent.

3.3.5 Greenhouse Gas Emissions Reductions

For this evaluation, Navigant defines GHG emissions impacts as the amount of CO_2 (in tons) offset by incentivized PV arrays. The SASH projects contributed to 10,922 tons of CO_2 emissions reductions from

[117] Note that the 2,699 sites in 2013 does not match the 3,164 total sites evaluated. That is because the CAISO peak happened in the summer and the SASH program interconnected 465 new sites between the 2013 CAISO peak and the end of the year.

2011–2013. Table 3-10 summarizes the CO_2 emission impacts by IOU and year. The annual emissions rates are sourced from the E3 CSI/SGIP Avoided Cost Calculator[118] as described in Section 2.2.8.

Table 3-10. SASH Actual Year GHG Reductions

Year	IOU	GHG Reduced (tons CO_2)	Total (tons CO_2)
2011	PG&E	326	618
	SCE	215	
	SDG&E	77	
2012	PG&E	1,862	3,663
	SCE	1,433	
	SDG&E	369	
2013	PG&E	3,285	6,641
	SCE	2,644	
	SDG&E	712	
Total			**10,922**

Source: Navigant Consulting, Inc.

3.3.6 Bill Impacts

Bill impacts are defined as the annual reduction in customers' electricity bills (in U.S. dollars) attributable to the PV systems incentivized by the program. Navigant estimated bill impacts for SASH customers based on modeled PV production and estimated load shapes per the methodology in Section 2.2.9. The team calculated bill impacts for both the first full year of operation as well as levelized over the 20-year life of the system. First-year impacts are the bill savings a customer could expect in the first full year following the installation of their PV system, using rate tariffs current as of January 2015. The levelized bill impacts present a more complete picture of potential bill savings over the life of the PV system and includes factors such as PV degradation, rate escalation over time, and economic inflation. Table 3-11 shows first full year bill impacts; Table 3-12 shows annual bill impacts levelized over the 20-year life of the system.

Table 3-11. SASH First-Year Participant Bill Savings (nominal $/participant)

Year	PG&E	SCE	SDG&E	Weighted Average
2011	$ 627	$ 692	$ 957	$ 689
2012	$ 752	$ 765	$ 858	$ 767
2013	$ 643	$ 798	$ 1,121	$ 794
Wtd. Avg.	**$ 688**	**$ 760**	**$ 995**	**$ 756**

Source: Navigant Consulting, Inc.

[118] E3 CSI/SGIP Avoided Cost Calculator, dated April 7, 2015.

Table 3-12. SASH Levelized Participant Annual Bill Savings (nominal $/participant)

Year	PG&E	SCE	SDG&E	Weighted Average
2011	$ 737	$ 825	$ 1,114	$ 812
2012	$ 847	$ 902	$ 1,054	$ 889
2013	$ 729	$ 920	$ 1,285	$ 909
Wtd. Avg.	**$ 785**	**$ 891**	**$ 1,168**	**$ 876**

Source: Navigant Consulting, Inc.

Many SASH customers are on CARE retail rates.[119] Because CARE rates are lower than standard residential retail rates, bill impacts for those customers are not as high (i.e., the PV installed for CARE customers is offsetting lower-cost electricity than for non-CARE customers). Note that customers in the CARE program must re-certify their CARE status every two years. If a customer is no longer eligible for CARE, their benefits may be greater than reported. Table 3-13 shows the difference between average levelized bill impacts for CARE versus non-CARE customers in the SASH program.

Table 3-13. SASH Levelized Bill Impacts, CARE vs. Non-CARE (nominal $/participant)

Year	CARE	Non-CARE
2011	$ 732	$ 1,102
2012	$ 784	$ 1,154
2013	$ 819	$ 1,224
Wtd. Avg.	**$ 782**	**$ 1,164**

Source: Navigant Consulting, Inc.

Bill impacts for SASH are significantly higher than those reported in the 2009–2010 impacts report.[120] This is due to two main factors:

- Greater fraction of customers on non-CARE billing rates in 2011–2013 (21 percent) than in 2009-2010 (three percent). Non-CARE rates have higher billing rates and thus greater bill savings.
- Larger average system size in 2011–2013 (3.1 kW-AC [CEC]) than in 2009–2010 (2.5 kW-AC [CEC]).

Another potential contributor is that the number of SASH sites has increased substantially from 330 in the evaluation cycle to 3,164 in 2011–2013 cycle. In addition, Navigant improved the bill impact

[119] The CARE program sets special energy billing rates for low-income customers. CARE customers receive a 30–35 percent discount on their electricity and gas bills. More information on CARE rates is available on the CPUC's website: http://www.cpuc.ca.gov/PUC/energy/Low+Income/care.htm.
[120] CSI SASH and MASH Impacts and Cost-Benefit Report. Available at: http://www.cpuc.ca.gov/NR/rdonlyres/13AAEDF8-BB7D-4FBD-AC05-3FC2B9CBF746/0/CSISASH_MASHImpact_and_Cost_Benefit_Report.pdf.

methodology with fewer simplifying assumptions and greater resolution at the IOU level. For example, the previous evaluation's bill impacts were based on applying rates from a single IOU (PG&E) across all SASH participants, while the current study includes rates from all three IOUs.

3.4 SASH COST-BENEFIT ANALYSIS FINDINGS

Navigant prepared a cost-benefit analysis that conformed to Decision 09-08-026.[121] Decision 09-08-026 adopted a methodology for evaluating distributed generation, including costs and benefits from societal, participant, and non-participant perspectives, consistent with the California SPM and the current framework used by the CPUC in evaluating other components of the CSI program. This section provides the cost-benefit ratios and net benefits resulting from the cost-effectiveness tests for the SASH program. Navigant modeled a scenario that excludes NEBs from the cost tests and a second scenario that includes NEBs. In addition, this section provides the results of the qualitative NEB review. This section is organized as follows:

- Section 3.4.1—SASH Cost-Benefit Test Results (Without NEBs)
- Section 3.4.2—SASH Cost-Benefit Test Results (Modified to Include NEBs)
- Section 3.4.3— SASH Qualitative Non-Energy Benefits

[121] California Public Utilities Commission, Decision Adopting Cost-Benefit Methodology for Distributed Generation, August 20, 2009. http://docs.cpuc.ca.gov/word_pdf/FINAL_DECISION/105926.pdf.

3.4.1 SASH Cost-Benefit Test Results (Without NEBs)

For all but the PCT, the cost-benefit ratios are less than one, meaning the costs exceed the benefits. Table 3-14 provides the SASH cost-benefit ratios without NEBs[122] and shows an upward trend in ratios over time. This trend is a function of escalating retail rates, avoided costs, and declining system equipment and installation costs.

Table 3-14. SASH Cost-Benefit Ratios without NEBs

Install Year	IOU	TRC	SCT	PAC	PCT	RIM
2011	PG&E	0.28	0.37	0.29	1.44	0.21
	SCE	0.28	0.38	0.29	1.48	0.21
	SDG&E	0.32	0.41	0.32	1.70	0.21
	Wtd. Avg.	0.28	0.38	0.29	1.48	0.21
2012	PG&E	0.31	0.41	0.32	1.49	0.23
	SCE	0.33	0.44	0.34	1.54	0.23
	SDG&E	0.35	0.46	0.36	1.71	0.23
	Wtd. Avg.	0.32	0.43	0.33	1.53	0.23
2013	PG&E	0.34	0.45	0.35	1.52	0.25
	SCE	0.36	0.47	0.37	1.62	0.25
	SDG&E	0.40	0.52	0.41	1.90	0.24
	Wtd. Avg.	0.36	0.47	0.37	1.63	0.25
Wtd. Avg.	**PG&E**	**0.31**	**0.41**	**0.32**	**1.48**	**0.23**
	SCE	**0.33**	**0.43**	**0.34**	**1.55**	**0.23**
	SDG&E	**0.36**	**0.47**	**0.37**	**1.79**	**0.23**
	Wtd. Avg.	**0.32**	**0.43**	**0.33**	**1.55**	**0.23**

Source: Navigant Consulting, Inc.

[122] Here NEBs refers to those non-energy benefits that could be quantifiably estimated from the limited LIPPT-adapted tests.

Net benefits without NEBs for each of the cost tests appear in Table 3-15. Net benefits are the NPV of all benefits less the NPV of all costs. Participants can expect $33.8 million in net benefits over the PV system lifetimes, while ratepayers can expect $73.3 million in net costs.

Table 3-15. SASH NPV of Net Benefits without NEBs ($)

Install Year	IOU	TRC	SCT	PAC	PCT	RIM
2011	PG&E	-6,755,441	-5,988,933	-6,509,087	3,722,060	-9,775,246
	SCE	-4,848,622	-4,270,582	-4,671,483	2,901,632	-7,202,762
	SDG&E	-1,400,417	-1,213,448	-1,345,476	1,282,163	-2,445,394
	Total	-13,004,480	-11,472,963	-12,526,045	7,905,854	-19,423,402
2012	PG&E	-10,736,293	-9,289,633	-10,318,117	7,134,504	-16,520,700
	SCE	-7,422,592	-6,322,861	-7,120,902	5,582,155	-11,946,275
	SDG&E	-1,614,034	-1,361,138	-1,547,626	1,620,134	-2,934,657
	Total	-19,772,919	-16,973,633	-18,986,646	14,336,794	-31,401,632
2013	PG&E	-4,697,493	-3,974,026	-4,505,197	3,310,134	-7,382,598
	SCE	-6,292,517	-5,244,407	-6,033,850	5,433,325	-10,691,094
	SDG&E	-2,111,740	-1,702,963	-2,017,872	2,851,599	-4,434,427
	Total	-13,101,750	-10,921,396	-12,556,919	11,595,058	-22,508,119
Total	**PG&E**	**-22,189,226**	**-19,252,592**	**-21,332,401**	**14,166,698**	**-33,678,544**
	SCE	**-18,563,732**	**-15,837,850**	**-17,826,234**	**13,917,112**	**-29,840,131**
	SDG&E	**-5,126,190**	**-4,277,549**	**-4,910,974**	**5,753,896**	**-9,814,478**
	Total	**-45,879,149**	**-39,367,991**	**-44,069,609**	**33,837,706**	**-73,333,153**

Source: Navigant Consulting, Inc.

3.4.2 SASH Cost-Benefit Test Results (Modified to Include NEBs)

Navigant used the LIPPT model to estimate NEBs for PG&E, SCE, and SDG&E for the SASH program. NEBs are benefits to the utility and benefits to participants. Navigant estimated first-year benefits and levelized benefits across a 20-year project period for projects installed in 2011, 2012, and 2013. In addition, the team estimated levelized benefits by utility for 2011 through 2013 weighted by the number of annual program participants (SASH homeowners). NEBs are comprised of two categories of benefits, utility benefits and participant benefits, with multiple types of benefits under each category.

Navigant estimated NEBs from the SASH program by IOU. First-year benefits in 2013 range from $137 for PG&E to $227 for SDG&E. The weighted average benefits by utility ranged from $153 for PG&E to $212 for SCE to $255 for SDG&E. For all of the benefits estimated in the NEB analysis, the results differ between IOUs because the average costs and bill impacts vary by IOU, and the costs and savings are the basis for the NEB calculation.

Table 3-16. SASH First-Year Non-Energy Benefits per Participating Household by Utility

	1st Year NEBs ($)	Levelized NEBs ($)	Program Wtd. Avg. NEBs ($)
PG&E			
2011	120	151	153
2012	141	154	
2013	137	155	
SCE			
2011	168	208	212
2012	179	212	
2013	187	216	
SDG&E			
2011	216	249	255
2012	201	253	
2013	227	259	

Note: Results rounded to the nearest dollar.
Source: Navigant Consulting, Inc.

Table 3-17 presents a breakdown of utility and participant NEBs by utility for SASH projects installed in 2013. The results show that the avoided rate subsidy for CARE payments makes up a large portion of the NEBs for SASH projects.

Table 3-17. Breakdown of Utility and Participant Non-Energy First-Year Benefits per Participating Household for SASH (2013)

SASH Program - Non-Energy Benefits (2013)	PG&E ($)	SCE ($)	SDG&E ($)
Utility Benefits			
Utility Rate Subsidy Avoided (CARE) Payments	95	149	179
Reduced Carrying Cost on Utility Arrearages	23	18	18
Utility Fewer Customer Calls	5	7	11
Utility Lower Bad Debt Written Off	2	2	5
Utility Fewer Notices	2	7	4
Utility Fewer Shutoffs	0	0	0
Utility Fewer Reconnects	0	0	0
Utility Reduced Collection Costs	0	0	0
Participant Benefits			
Participant Reduced Homelessness and Mobility	4	2	4
Participant Net Household Benefits from Additional Hardship Benefits	4	1	4
Participant Fewer Shutoffs	1	1	1
Participant Fewer Calls to Utility	1	0	1
Participant Fewer Reconnects	0	0	0
Participant Property Value Benefits	0	0	0
Total Benefits	**137**	**187**	**227**

Note: Results rounded to the nearest dollar.
Source: Navigant Consulting, Inc.

Table 3-18 shows the cost-benefit ratios with NEBs. The inclusion of NEBs increased the cost-benefit ratios by 29 percent for the TRC, 22 percent for the SCT, 28 percent for the PAC and RIM, and four percent for the PCT. The PCT's smaller increase reflects the fact that participants only receive about four percent of the total value of NEBs, while the IOUs receive the remaining 96 percent (on a levelized $/participant-year basis).

Table 3-18. SASH Cost-Benefit Ratios with Inclusion of NEBs

Install Year	IOU	TRC	SCT	PAC	PCT	RIM
2011	PG&E	0.35	0.44	0.35	1.45	0.26
	SCE	0.38	0.47	0.39	1.48	0.28
	SDG&E	0.44	0.54	0.44	1.71	0.29
	Wtd. Avg.	0.37	0.46	0.38	1.49	0.27
2012	PG&E	0.38	0.48	0.39	1.50	0.28
	SCE	0.43	0.54	0.44	1.54	0.31
	SDG&E	0.49	0.60	0.50	1.72	0.32
	Wtd. Avg.	0.41	0.51	0.42	1.53	0.29
2013	PG&E	0.43	0.54	0.44	1.53	0.31
	SCE	0.47	0.58	0.48	1.62	0.32
	SDG&E	0.53	0.66	0.54	1.91	0.32
	Wtd. Avg.	0.47	0.58	0.47	1.64	0.32
Wtd. Avg.	**PG&E**	**0.38**	**0.48**	**0.39**	**1.49**	**0.28**
	SCE	**0.43**	**0.54**	**0.44**	**1.55**	**0.30**
	SDG&E	**0.50**	**0.61**	**0.50**	**1.80**	**0.31**
	Wtd. Avg.	**0.42**	**0.52**	**0.42**	**1.55**	**0.29**

Source: Navigant Consulting, Inc.

After including NEBs in the cost tests, net benefits improved by 14 percent for the TRC and PCT, 16 percent for the SCT, one percent for the PCT, and eight percent for the RIM. Table 3-19 shows that NEBs increase net benefits to $34.2 million for participants and decrease net costs to $67.2 million for the ratepayers.

Table 3-19. SASH Net Benefits with Inclusion of NEBs ($)

Install Year	IOU	TRC	SCT	PAC	PCT	RIM
2011	PG&E	-6,072,949	-5,306,441	-5,885,248	3,780,713	-9,151,406
	SCE	-4,194,165	-3,616,125	-4,034,524	2,919,131	-6,565,804
	SDG&E	-1,149,238	-962,270	-1,106,720	1,294,586	-2,206,639
	Total	-11,416,352	-9,884,835	-11,026,492	7,994,429	-17,923,849
2012	PG&E	-9,611,105	-8,164,446	-9,290,241	7,231,815	-15,492,823
	SCE	-6,273,358	-5,173,627	-6,000,938	5,611,425	-10,826,311
	SDG&E	-1,255,503	-1,002,608	-1,206,146	1,637,185	-2,593,177
	Total	-17,139,967	-14,340,681	-16,497,325	14,480,425	-28,912,312
2013	PG&E	-4,049,536	-3,326,069	-3,912,841	3,365,735	-6,790,242
	SCE	-5,217,673	-4,169,562	-4,985,683	5,460,003	-9,642,927
	SDG&E	-1,633,511	-1,224,734	-1,561,677	2,873,633	-3,978,232
	Total	-10,900,719	-8,720,365	-10,460,201	11,699,370	-20,411,401
Total	**PG&E**	**-19,733,589**	**-16,796,955**	**-19,088,329**	**14,378,263**	**-31,434,472**
	SCE	**-15,685,196**	**-12,959,314**	**-15,021,145**	**13,990,559**	**-27,035,042**
	SDG&E	**-4,038,252**	**-3,189,611**	**-3,874,544**	**5,805,404**	**-8,778,048**
	Total	**-39,457,038**	**-32,945,881**	**-37,984,018**	**34,174,225**	**-67,247,562**

Source: Navigant Consulting, Inc.

3.4.3 SASH Qualitative Non-Energy Benefits

Navigant conducted a qualitative assessment of NEBs to supplement the top-down quantitative analysis done through the LIPPT model. Because the LIPPT model addresses benefits of low-income energy efficiency programs, the approach includes some, but probably not all, of the benefits that might reasonably apply to a low-income solar program.

To identify additional NEBs for the SASH program, Navigant leveraged in-depth interviews and participant surveys from the Market and Program Administrator Assessment[123] to gather market actor input on the scope and scale of likely program-related NEBs and costs. Navigant conducted focused meetings with the PAs and the SASH/MASH Measurement and Evaluation (M&E) Team to discuss and prioritize the NEB topics used in subsequent interviews and surveys.

[123] Navigant Consulting, Inc. "California Solar Initiative—Biennial Evaluation Studies for the Single-Family Affordable Solar Homes (SASH) and Multifamily Affordable Solar Housing (MASH) Low-Income Programs: Market and Program Administrator Assessment, Program Years 2011–2013." Prepared for the California Public Utilities Commission.

The team did not expect this limited inquiry to result in robust or comprehensive estimates of solar-specific NEBs. Instead, the results should provide initial, qualitative information to guide future evaluations' prioritization and development of more defensible estimates of those non-energy elements. Beyond energy bill savings for SASH participating homeowners, the SASH program provides additional NEBs to homeowners, job trainees, subcontractors, and the community.[124] The Navigant team asked homeowners about NEBs as part of the survey of 100 SASH participants. The team also interviewed program market actors including GRID Alternatives, SASH subcontractors participating in the Sub-Contractor Partnership Program (SPP), job trainees, and job training organizations. This research indicated that NEBs, although difficult to quantify, added additional value to the SASH program.

3.4.3.1 Participant Homeowner Perspective

Navigant asked SASH homeowners what benefits they considered when deciding whether to install a solar PV system on their home. The results in Table 3-20 show that a majority of homeowners (69 percent) mentioned the financial benefits such as long-term savings (69 percent) and protection against future utility rate increases (15 percent). Secondly, 31 percent cited helping the environment as a benefit resulting from the installation of solar. Homeowners also considered independence from the electric utility (six percent), improving the value of their home (four percent), and their neighbors and friends who are going solar (three percent) as other positive impacts resulting from the installation of solar on their homes. This result is consistent with the results described above where environmental benefits are the most common NEB.

Table 3-20. Other Benefits Considered When Deciding to Install Solar (SASH)

Survey Question: What benefits of solar did you consider before deciding to install the system?	
Response	**Percent**
Save money in the long run*	69
Helping the environment/reducing personal carbon footprint/reducing pollution	31
Protection against future electric utility rate increases	15
Self-sufficiency/going "off the grid"/independence from electric utility	6
To improve the value of my home	4
My friends/neighbors/people I admire are going solar	3
Available rebates	2
Other specified	6
Don't know	1
Total Responses	**137**

Note: Respondents could provide more than one response, so total does not sum to 100%.
Source: SASH participant survey, 2014 (n=100)

[124] Section 3.4.3.1 presents the benefits to homeowners and Section 3.4.3.2 presents the benefits to other market actors.

Navigant also asked SASH homeowners if they noticed any other positive impacts or benefits resulting from the installation of solar on their home besides making their energy bills more affordable. The results in Table 3-21 show that most homeowners did not consider any additional benefits beyond the economic benefit of electric bill savings when deciding to install solar. The most commonly mentioned benefit was the environmental benefits of installing solar (19 percent) followed by pride in one's home (three percent).

Table 3-21. Positive Impacts Resulting from Solar PV Beyond Energy Savings (SASH)

Survey Question: Have you noticed any other benefits resulting from solar system other than lower bills?	
Response	**Percent**
Environmental benefits/going green/reducing pollution	19
Pride in our home	3
Other specified	6
No benefits beyond electric bill savings	69
Don't know	5

Note: Respondents could provide more than one response, so total does add up to 100%.
*It appears that many survey respondents essentially provided the answer that the question asked to leave out. However, the distribution of the rest of the responses gives an idea of the respondents' other perceived benefits of the program.
Source: SASH participant survey, 2014 (n=100)

3.4.3.2 *Market Actor Perspective*

Navigant asked program market actors about potential NEBs of the SASH program as part of the in-depth interviews for the Market and Program Administrator Assessment. The team interviewed staff members from GRID Alternatives, SASH subcontractors participating in the SPP, job trainees in the SPP program, and job training organizations. The research team first asked the respondents to describe the benefits of the SASH program beyond energy savings. The team then asked how the SASH program benefitted specific entities such as the environment, the individual respondent, the electric grid, low-income homeowners and communities, the utility, and the economy. The most common NEBs mentioned across SASH market actors included improved quality of life for SASH homeowners, training benefits to job trainees, and pride in one's community for SASH homeowners. This section summarizes the NEBs described in the interviews.

- **Environmental benefits:** Market actors described the environmental and climate benefits of solar, often due to reduced use of fossil fuels such as natural gas and coal, and increased environmental awareness after a homeowner installs the solar PV system. One SASH job training organization explained their feelings about the environmental benefits of solar by explaining, "Any solar is [likely] going to take a little bit of natural gas off the grid, so there is going to be some climate benefits and some health benefits to those living around the power plant from reduced emissions."
- **Education and environmental awareness benefits:** Market actors believe that homeowners learn about solar energy and the environmental benefits of solar as a result of participating in the SASH program. Further, one respondent indicated that the education that accompanies a solar install

makes homeowners more aware of their energy consumption and waste habits, in turn making them more likely to conserve. Respondents also explained that communities could become more educated about solar when their neighbors participate in the program because they are curious and often express interest in learning about their neighbor's solar installation.

- **Job training benefits:** All SASH job training organizations commented on the educational value of the SASH program, which allowed them to offer their students hands-on experiences. As one person explained, "It has helped guide people, and provided some job placement."
- **Subcontractor benefits:** SASH SPP subcontractors had positive things to say about how they have benefitted from the SASH program. The subcontractors explained that participating in the SASH program has created more business opportunities and jobs within their companies and has given their company more credibility and confidence. One subcontractor explained the benefits with the following statement: "GRID having a higher standard allowed me to learn a good process, and helped me with the technology and helped me with the customer base."
- **Quality of life benefits to low-income homeowners:** Many respondents described how the SASH program improves quality of life for low-income homeowners. For example, several respondents mentioned that installing solar helps homeowners save money on their utility bills, which in turn allows them to run their air conditioning and improve the comfort in their homes.
- **Community pride:** Several market actors noted that the SASH program increases pride in one's home and neighborhood after installing solar. As one person described, "emotionally it [the program] helps the homeowner and the community. Because they have solar and they are proud of their property."
- **Economic benefits:** Although some SASH program actors were unsure of the economic benefits of the program, the majority of interviewees believed that the SASH program benefits the economy by saving homeowners money and giving them disposable income to spend, boosting the economy. The program has also trained workers and provided them with jobs, which enables them to spend money and keep the economy going. Additionally, the SASH program experience has helped trainees find jobs elsewhere in the economy. As one subcontractor explained, with the latest economic downturn, "It [SASH program] is the best thing in the past 6-7 years. I have friends who were electricians and roofers who were out of jobs and jumped into this. I don't know if solar was not here, what I would have done or what many roofers or electricians would have done."
- **Benefits to the utility:** Respondents' opinions differed in whether they believe that solar installed through the SASH program has benefitted or harmed the utility. Some of the benefits of solar included not needing to generate as much electricity or purchase as much electricity from other utilities or independent power producers. One respondent added that solar takes stress off the grid as its generation aligns with peak electricity consumption in the afternoon.

  Many others felt that the solar installed through the SASH program actually threatened the utility, as customers' bills are now lower. As one SASH job training organization described, "For the electric utility, I think it is causing more headaches than anything else. And then I think they are scrambling to do due diligence on how the solar is going to affect them on a power flow, stability and substation level." Others believed the program neither benefitted nor harmed the utility, as this program is small in comparison to the electricity generation of the utilities in California and, as a result, has marginal impact.

3.4.3.3 Most Significant SASH Benefits

SASH homeowners and other market actors agree that reducing homeowner utility bills and benefits to the environment were the two most important SASH program benefits. Multiple respondents also indicated that improving the lives of people and low-income communities was the most significant aspect of the program. Respondents also offered education, job training, and the economy as the most significant benefit of the program.

4 MASH Findings

The evaluation of the MASH program shows that the PV systems are installed and operating as intended and that the program is cost-effective only from the PCT perspective.

This section presents the MASH findings in a similar structure to the methodology section and includes the following topics:

- Section 4.1—Summary of Installed MASH Projects
- Section 4.2—MASH Desk Review and Field Verification Findings
- Section 4.3—MASH Impact Analysis Findings
- Section 4.4—MASH Cost-Benefit Analysis Findings

4.1 SUMMARY OF INSTALLED MASH PROJECTS

The MASH program installed 273 projects between 2011 and 2013, providing 18,400 kW-DC (PTC) of interconnected capacity. By contrast, between 2009 and 2010, 34 MASH projects were completed, representing 1,933 kW-DC (PTC)[125] of installed capacity. For maps showing geographic distribution of installed projects, see the Market and Program Administrator Assessment.[126] The rate of new system installations saw a steady increase in installed capacity annually between 2011 and 2012, while 2013 saw significantly fewer installations. Table 4-1 shows new interconnected capacity by quarter from the beginning of 2011 to the end of 2013. Figure 4-1 shows the same data graphed on a monthly basis since

[125] The 2009–2010 MASH installed capacity was reported in kW-AC (CEC). Using the definition of CEC-AC rating as the DC (PTC) rating times inverter efficiency, Navigant estimated kW-DC PTC capacity by dividing the reported 1,846 kW-AC (CEC) by the calculated average MASH inverter efficiency of 0.955.

[126] Navigant Consulting, Inc. "California Solar Initiative—Biennial Evaluation Studies for the Single-Family Affordable Solar Homes (SASH) and Multifamily Affordable Solar Housing (MASH) Low-Income Programs: Market and Program Administrator Assessment, Program Years 2011–2013." Prepared for the California Public Utilities Commission.

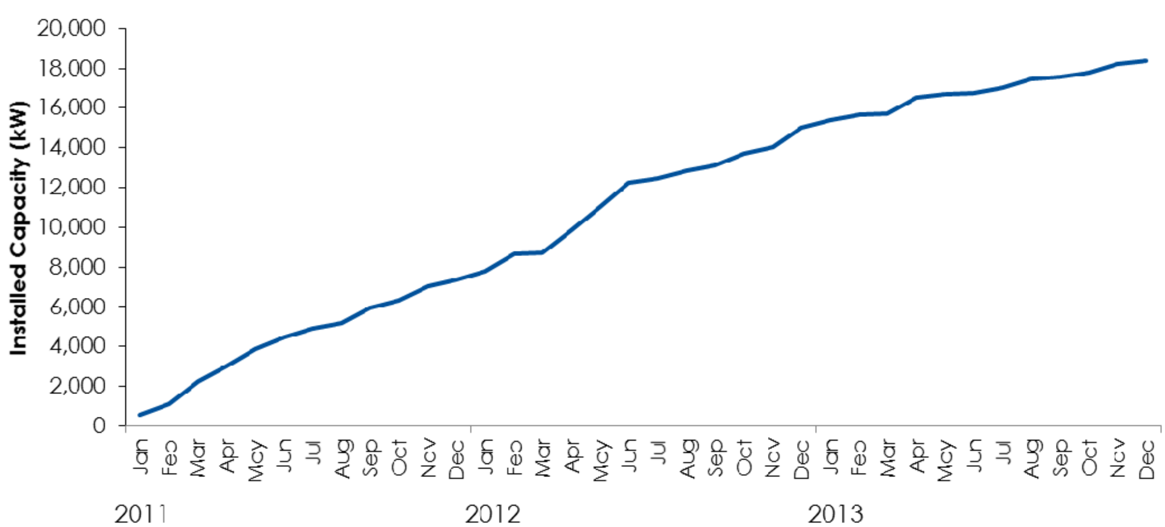
the beginning of 2011. The variability in installed capacity between quarters is due to the variation in installed project sizes.

Table 4-1. MASH New Interconnected Capacity by Quarter

Year	Quarter	New Capacity Since Previous. Quarter (kW-DC [PTC])	Cumulative Number of Projects	Cumulative Capacity (kW-DC [PTC])
2011	1	2,254	32	2,254
	2	2,206	75	4,460
	3	1,468	102	5,928
	4	1,445	131	7,373
2012	1	1,354	158	8,727
	2	3,495	192	12,222
	3	896	199	13,118
	4	1,899	226	15,017
2013	1	707	238	15,724
	2	1,032	249	16,756
	3	819	259	17,575
	4	825	273	18,400

Source: Navigant analysis of PowerClerk database

Figure 4-1. MASH New Interconnected Capacity for 2011-2013 (kW-DC [PTC])



Note: Does not include capacity installed/interconnected before 2011.
Source: Navigant analysis of PowerClerk database

4.2 MASH DESK REVIEW AND FIELD VERIFICATION FINDINGS

The goal of the field verification was to verify the installed capacity and system characteristics for model input. In addition to the field verification, Navigant completed a desk review for a sample of projects. This section presents the findings from the desk review and field verification. The desk review found some minor record-keeping discrepancies, while the field verification uncovered some issues related to measuring and documenting of PV system characteristics. Overall, these had little effect on the DFVR.

This section is organized as follows:

- Section 4.2.1—Desk Review Findings
- Section 4.2.2—Field Verification Findings

4.2.1 Desk Review Findings

Navigant encountered a number of issues while completing the desk review, as outlined below.

- **Clerical errors:** Every parameter claimed in the PowerClerk database should be traceable to the underlying third-party verified documentation. However, a significant number of projects in the MASH data system have parameters that do not match third-party verified inspection worksheets. Based on the field verification, three out of five MASH projects had at least one discrepancy for either module grouping, tilt, or azimuth.
- **Database errors preventing report generation:** Even though PowerClerk does track monthly shading values by array, Navigant encountered errors when trying to export the shading values. The sites with a high number of arrays cause the dataset to become very wide (i.e., having a large number of columns), possibly causing the error.
- **Lack of universal project primary keys:** A primary key, in relational database terms, is a unique identifier that persistently identifies a record through time. Each MASH project should contain a primary key that is referenced in all documents relating to that project. Additionally, each array within a given project should also have a primary key. PowerClerk contains primary keys for both projects and arrays; however, third-party inspections do not always refer to the primary keys listed in PowerClerk, making manual intervention necessary to match PowerClerk listings with third-party inspections. All changes made to a project (original design, installed system, results of the third-party inspection, EPBB runs, etc.) should be based on this primary key so that they are easy for evaluators to follow.
- **Inconsistent sampling protocol by third-party inspectors:** The desk review sample included five large arrays (>130 kW-DC [PTC]). At the large PG&E sites, the third-party inspectors selected and reviewed only a sample of the arrays (seven of 29 in one case, and eight of 17 in another). Only PG&E inspectors appear to use a sampling strategy like this. At one of the large SCE sites, the third-party inspectors filled out only three of 24 FIWS, but notes indicated the other arrays were checked fully with no discrepancies found. The result of this finding is that the usefulness of conducting a desk review for those sites is limited because little third-party verified data is available.

In addition, Navigant encountered several other issues with data quality and accessibility. Appendix A contains a number of data-related recommendations as well as a memo Navigant sent the CPUC on January 15, 2015, outlining issues accessing evaluation data.

4.2.2 Field Verification Findings

While the MASH PV installations generally matched what was listed in the program tracking database, Navigant's field inspectors did uncover two types of discrepancies—incorrect panel counts and incorrect tilt and azimuth values. In the case of each of these discrepancies, the third-party inspectors did not uncover the issue during their review. In addition to these discrepancies, the team found soiling at one MASH project. The overall impact of these issues was minor. These issues are detailed further below:

- **Panel counts:** At two separate MASH sites, the number of panels in each array was different from the third-party inspection reports. In one case, the total number of panels reported in PowerClerk (and by the third-party inspector) was one too many, representing 0.4 percent of the site's kW-DC (STC) capacity and reducing the site's DF by 0.5 percent. In the other case, the total number of panels reported in PowerClerk was 20 panels too few, representing 2.5 percent of the site's capacity and increasing the site's overall DF by 1.4 percent.
- **Tilt and azimuth:** Navigant field crews found two MASH arrays where the measured tilt differed from the tracking database values by three degrees or more. Navigant also found six arrays where measured azimuth differed from database values by more than five degrees. Two of the azimuth discrepancies were off by more than 10 degrees, potentially signifying that magnetic bearings were not consistently being converted to true bearings (the difference between true north and magnetic north, called magnetic declination, ranges from 12 degrees to 16 degrees in California depending on location). For more background information on correctly accounting for magnetic declination, see the field protocol in Appendix B.4
- **Damage and soiling:** When onsite, Navigant crews inspected the systems for any apparent damage, theft, or vandalism. Navigant field crews found no instances of theft or vandalism, although one module at a MASH site was cracked with unknown apparent cause. The only other factor that Navigant found during the field study that would affect system performance

was soiling on panel surfaces. One MASH site, in particular, was located near a dusty fairground in a dry region and had a high degree of soiling, as shown in Figure 4-2.

Figure 4-2. Extreme Soiling near a Dusty Fairground (Bottom Cell Cleaned for Visual Comparison)

Source: Navigant Consulting, Inc.

4.3 MASH IMPACT ANALYSIS FINDINGS

The team completed the impact analysis of MASH projects to meet the following objectives. This section details the findings of each of these objectives.

- Produce estimates of the following parameters:
  - Section 4.3.1—Design Factor Verification Rate (unitless)
  - Section 4.3.2—Energy production (MWh)
  - Section 4.3.3—Capacity factor (unitless)
  - Section 4.3.4—Demand reduction (CAISO peak/IOU peak, kW-AC [meter])
  - Section 4.3.5—Greenhouse gas emissions reduction (tons CO_2)
  - Section 4.3.6—Assess bill impacts for participating customers ($ per customer)
  - Section 4.3.7—Understand the degree to which tenants served by MASH projects receive benefits from the program

4.3.1 Design Factor Verification Rate

As discussed in Section 2.1, the primary output from the desk review and field verification is the DFVR. Consistent with the 2009–2010 SASH evaluation, DFVR for MASH was very close to 1.0.[127] The analysis meets the 90/30 confidence/precision target even given the relatively small sample size. Table 4-2 shows the results of the DFVR calculation.

Table 4-2. MASH DFVR

Parameter	Design Factor Verification Rate
Mean	0.997
Standard deviation	0.021
Standard error	0.009
Z value at 90% confidence interval (4 degrees of freedom)	2.132
Relative precision at 90% confidence interval	2.0%

Source: Navigant Consulting, Inc.

Another metric Navigant calculated was the CERR, which tracks the effects of clerical errors introduced while entering array characteristics and EPBB calculator results into the database. MASH had DF-specific clerical errors in eight of 88 sampled arrays, which only slightly impacted the CERR. PowerClerk tracks MASH DF separately by array as well as by site. Table 4-3 shows the results of calculating the CERR for the sampled MASH sites.

Table 4-3. MASH CERR

Parameter	CERR
Mean	1.001
Standard deviation	0.002
Standard error	0.001
Z value at 90% confidence interval (4 degrees of freedom)	2.132
Relative precision at 90% confidence interval	0.23%

Source: Navigant Consulting, Inc.

4.3.2 Energy Production

Understanding a program's energy impacts is important because it gives a sense for the scale of the program and a metric for comparison with other programs. Navigant defines energy impacts in this evaluation as the annual electrical energy (MWh) produced by program-incentivized PV arrays. For

[127] Navigant Consulting, Inc. California Solar Initiative *Low- Income Solar Program Evaluation: Program Impacts and Cost-Benefit Report Program Years 2009-2010.* Prepared for the California Public Utilities Commission.

energy impacts, Navigant reported energy production using both the actual year 8,760 production shapes and typical 8,760 load shapes using TMY data (referred to as typical year). Actual year gives a retrospective estimate of the impacts in 2011-–2013, while the typical year impacts are more representative of what the systems are likely to produce yearly in the future. The findings of impacts from both views, actual year and typical year, are presented in this section.

4.3.2.1 Actual Year Energy Impacts

The MASH PV arrays installed during 2011–2013 generated approximately 60,191 MWh of electricity through the end of 2013. Table 4-4 and Table 4-5 show the results of the energy impact calculations modeled using actual historic conditions. Navigant discarded any PV production modeled before each system's interconnection date for actual year impacts. Note that these tables present the energy impacts as seen by the electric grid—i.e., the 2011 energy production total contains energy produced in 2011 only by those sites installed throughout 2011, while 2013 energy production includes energy produced in 2013 by systems installed throughout 2011, 2012, and 2013. The total at the bottom refers to the total energy production attributable to MASH from 2011–2013.

Table 4-4. Actual Year Energy Impacts of MASH Projects

Install Year	Total Energy (MWh)
2011	7,436
2012	20,938
2013	31,817
Total	**60,191**

Source: Navigant Consulting, Inc.

Table 4-5. Actual Year Energy Impacts of Installed MASH Projects by Year and Quarter (MWh)

Year	IOU	Q1 MWh	Q2 MWh	Q3 MWh	Q4 MWh	Total
2011	PG&E	77	722	1,174	897	**2,869**
	SCE	133	907	1,123	795	**2,958**
	SDG&E	171	432	518	488	**1,608**
2012	PG&E	1,278	2,639	2,952	1,664	**8,532**
	SCE	1,308	2,837	3,046	1,926	**9,117**
	SDG&E	660	949	992	688	**3,289**
2013	PG&E	2,357	3,891	3,740	2,366	**12,354**
	SCE	3,062	4,942	4,578	2,950	**15,532**
	SDG&E	873	1,136	1,118	805	**3,931**

Source: Navigant Consulting, Inc.

4.3.2.2 *Typical Year Energy Impacts*

Assuming typical weather conditions, the 273 MASH projects installed in 2011–2013 generate between about 6,000 MWh and 15,000 MWh of electricity each year depending on the install year. Table 4-6 shows the typical year impacts by install year, while Table 4-7 shows the same data broken down by IOU and quarter. Note that the total typical year production shown in Table 4-6 is substantially lower than the total actual year production presented in Table 4-4. This is because Table 4-6's total represents the sum of three single years' typical energy production while Table 4-4's total refers to total actual year production summed over that three-year period and does not include production from before each project's interconnect date.

Table 4-6. Typical Year Energy Impacts of MASH Projects Online by End of Year

Install Year	MWh
2011	14,261
2012	14,954
2013	6,411
Total	**35,626**

Source: Navigant Consulting, Inc.

Table 4-7. Typical Year Energy Impacts of Installed MASH Projects by Year and Quarter (MWh)

Year	IOU	Q1 MWh	Q2 MWh	Q3 MWh	Q4 MWh	Total
2011	PG&E	1,232	2,135	1,997	1,121	**6,485**
	SCE	1,047	1,524	1,393	943	**4,906**
	SDG&E	616	839	852	562	**2,869**
2012	PG&E	888	1,453	1,407	792	**4,541**
	SCE	1,921	2,852	2,703	1,680	**9,156**
	SDG&E	266	385	374	233	**1,257**
2013	PG&E	532	960	916	495	**2,903**
	SCE	625	940	891	549	**3,003**
	SDG&E	105	157	150	93	**504**

Source: Navigant Consulting, Inc.

4.3.3 Capacity Factor

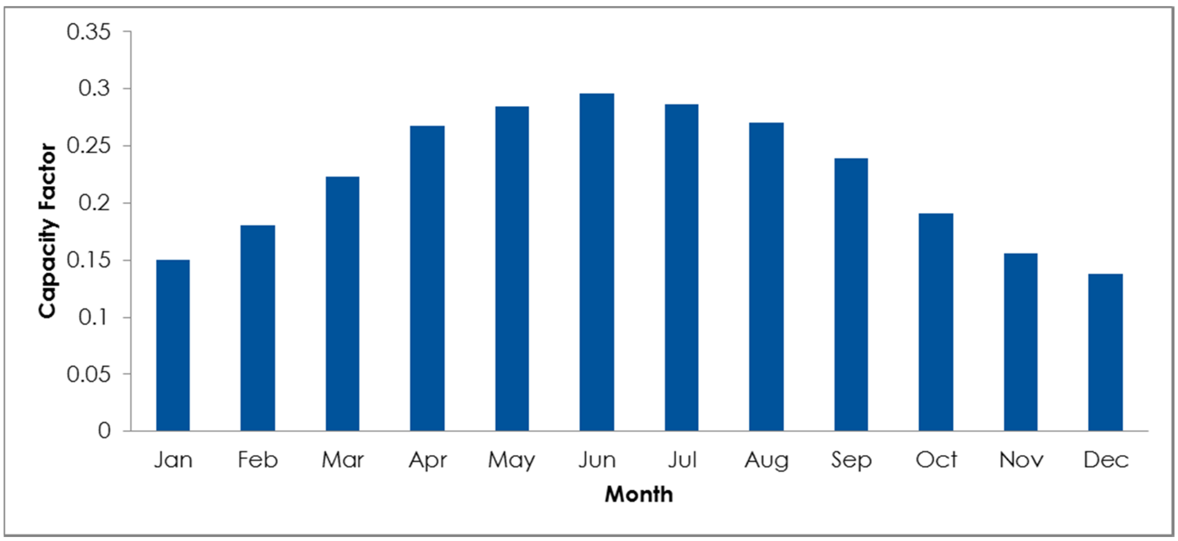
CF is a ratio of the actual output of a system during a specified time period to the theoretical rated capacity of that system during the same timeframe. CF is a metric used in the power industry to describe the reliability of power plants. For PV generation, it can be used to compare efficacy and available solar resources across one or many PV systems. Table 4-8 summarizes the program-wide annual CF by year. The annual CF varied each year and ranged from 22.1 percent to 22.7 percent. Figure 4-3 shows the average CF by month for all projects installed in 2011–2013. Differences in CF over time are primarily attributable to changes in weather or, more specifically, the amount of incident solar radiation on the PV system. Factors like solar geometry, shading, and equipment efficiency are installation-specific factors, which influence capacity factors. For CFs by IOU, see Appendix D.

Table 4-8. MASH Program-Wide Capacity Factors for 2011–2013

Install Year	Capacity Factor
2011	22.1%
2012	22.7%
2013	22.2%

Source: Navigant Consulting, Inc.

Figure 4-3. MASH Capacity Factor by Month Averaged over 2011–2013



Source: Navigant Consulting, Inc.

4.3.4 Demand Reduction

Navigant calculated MASH demand reduction impacts during CAISO's peak hour by summing the modeled (actual weather) kWh energy production during those hours by IOU and year. Peak hour refers to the hour during which the actual system-wide peak occurred. For peak demand impacts, Navigant used actual weather and discarded any PV production modeled before each system's interconnection date (Navigant refers to this case as actual year).

Table 4-9 shows the number of projects online by the time of the CAISO system peak demand in each year (for details see Section 2.2.7). In addition, the table shows the installed capacity by the time of the peak demand reduction. At the time of CAISO peak, Navigant models estimated a peak demand reduction of about 2,272 kW-AC (meter) in 2011. In 2012, the 196 projects installed before the date of the CAISO peak were responsible for an approximate 7,641 kW-AC (meter) peak reduction. By the time of the 2013 CAISO peak, 249 projects were contributing to peak demand reductions for a total of 9,594 kW-AC (meter). For utility-specific peak demand reductions, see Appendix C.

Table 4-9. CAISO Peak Demand Reductions Attributable to Interconnected MASH Systems

Year	# of Sites Online	Installed Capacity (kW-DC [PTC])	Demand Reduction (kW-AC [meter])	Peak Capacity Factor
2011	91	5,253	2,272	43%
2012	196	12,443	7,641	61%
2013	249[128]	16,756	9,594	57%

Source: Navigant Consulting, Inc.

In addition, Table 4-9 shows the peak capacity factor, which is the ratio of peak power production to the total CEC-AC rating of the PV arrays installed and interconnected before the date of the peak event. It is a metric of how favorable conditions were for solar power production during the peak time and accounts for factors such as geographic distribution of the arrays, tilt, azimuth, shading, cloud cover, and time of day. Peak capacity factors ranged from 43 percent to 61 percent.

4.3.5 Greenhouse Gas Emissions Reduction

For this evaluation, Navigant defines GHG emissions impacts as the amount of CO_2 (in tons) offset by incentivized PV arrays. The MASH program solar PV systems were responsible for 27,452 tons of CO_2 emissions reductions from 2011–2013. Table 4-10 summarizes the CO_2 emissions impacts by IOU. The

[128] Note that 249 projects in 2013 does not match the 273 total MASH projects evaluated. That is because the CAISO peak happened in the summer and the MASH program interconnected 24 new projects between the 2013 CAISO peak and the end of the year.

annual emissions rates come from the E3 CSI/SGIP Avoided Cost Calculator,[129] as described in Section 2.2.8.

Table 4-10. MASH Actual Year GHG Reductions

Year	IOU	GHG Reduced (tons CO_2)	Total
2011	PG&E	1,102	2,857
	SCE	1,136	
	SDG&E	618	
2012	PG&E	4,181	10,261
	SCE	4,468	
	SDG&E	1,612	
2013	PG&E	5,566	14,334
	SCE	6,997	
	SDG&E	1,771	
Total			**27,452**

Source: Navigant Consulting, Inc.

4.3.6 Bill Impacts

Bill impacts are defined as the annual reduction in customers' electricity bills (in U.S. dollars) attributable to the PV systems incentivized by the program. Navigant estimated bill impacts separately for MASH tenants and owners based on modeled PV production, tenant/owner allocation percentages, and estimated load shapes per the methodology in Section 2.2.9. The team calculated bill impacts for the first full year of operation as well as levelized over the 20-year life of the system. First-year impacts are the bill savings a customer could expect in the first full year following the installation of their PV system using rate tariffs as of January 2015. The levelized bill impacts present a more complete picture of potential bill savings over the life of the PV system and include factors such as PV degradation, rate escalation over time, and economic inflation. Table 4-11 shows first full year tenant bill impacts, while Table 4-12 shows tenant impacts levelized over the 20-year life of the system.

Table 4-11. MASH First-Year Tenant Bill Savings (nominal $/participant)

Year	PG&E	SCE	SDG&E	Weighted Average
2011	$ 379	$ 370	$ 675	$ 492
2012	$ 753	$ 287	$ 536	$ 563
2013	$ 458	$ 281	$ 496	$ 365
Wtd. Avg.	**$ 530**	**$ 297**	**$ 614**	**$ 484**

Source: Navigant Consulting, Inc.

[129] E3 CSI/SGIP Avoided Cost Calculator, dated April 7, 2015.

Table 4-12. MASH Levelized Tenant Bill Savings (nominal $/participant)

Year	PG&E	SCE	SDG&E	Weighted Average
2011	$ 410	$ 415	$ 737	$ 537
2012	$ 899	$ 321	$ 490	$ 634
2013	$ 381	$ 298	$ 441	$ 343
Wtd. Avg.	**$ 584**	**$ 324**	**$ 631**	**$ 521**

Source: Navigant Consulting, Inc.

Many MASH tenants are on CARE retail rates. Because CARE rates are lower than standard residential retail rates, bill impacts for those customers are also lower (i.e., the PV installed for CARE customers is offsetting lower-cost electricity than for non-CARE customers). Table 4-13 shows the difference between average levelized bill impacts for CARE versus non-CARE tenants.

Table 4-13. MASH Levelized Tenant Bill Impacts, CARE vs. Non-CARE (nominal $/participant)

Year	CARE	Non-CARE
2011	$ 540	$ 647
2012	$ 401	$ 549
2013	$ 197	$ 434
Wtd. Avg.	**$ 397**	**$ 562**

Source: Navigant Consulting, Inc.

Owner bill savings depended heavily on the allocated PV capacity and were quite variable on a per-project basis. Navigant calculated owner bill impacts on a per-kW-DC (STC) basis for clarity. Table 4-14 shows first-year owner bill savings, while Table 4-15 shows levelized owner bill savings.

Table 4-14. MASH First-Year Owner Bill Savings (nominal $/kW-DC [STC])

Year	PG&E	SCE	SDG&E	Weighted Average
2011	$ 402	$ 404	$ 443	$ 405
2012	$ 411	$ 396	$ 454	$ 401
2013	$ 423	$ 393	$ 475	$ 410
Wtd. Avg.	**$ 409**	**$ 398**	**$ 450**	**$ 404**

Source: Navigant Consulting, Inc.

Table 4-15. MASH Levelized Owner Bill Savings (nominal $/kW-DC [STC])

Year	PG&E	SCE	SDG&E	Weighted Average
2011	$ 451	$ 446	$ 485	$ 451
2012	$ 440	$ 438	$ 512	$ 441
2013	$ 441	$ 450	$ 480	$ 446
Wtd. Avg.	**$ 446**	**$ 442**	**$ 496**	**$ 445**

Source: Navigant Consulting, Inc.

During the 2009–2010 evaluation, there were not enough completed MASH projects to warrant an impacts or cost-benefit analysis. Therefore, there is no point of comparison against a previous evaluation.

4.3.7 MASH Tenant Impacts

One of the impacts goals was to understand the degree to which tenants served by MASH projects receive benefits from the program. The primary tenant benefits are the bill savings. Additionally, the NEB analysis found other benefits that the tenants receive. For quantitative NEB findings relating to MASH tenants, refer to Section 4.4.2. For qualitative findings, refer to Section 4.4.3. Additionally, the Market and Program Administrator Assessment report contains a section on tenant experiences, which includes further information on benefits MASH tenants received based on a survey of MASH tenants.

4.4 MASH COST-BENEFIT ANALYSIS FINDINGS

Navigant prepared a cost-benefit analysis that conformed to Decision 09-08-026.[130] Decision 09-08-026 adopted a methodology for evaluating distributed generation, including costs and benefits from societal, participant, and non-participant perspectives, consistent with the California SPM and the current framework used by the CPUC in evaluating other components of the CSI program. This section provides the cost-benefit ratios and net benefits resulting from the cost-effectiveness tests for the MASH program. Navigant modeled a scenario that excludes NEBs from the cost tests and a second scenario that includes NEBs. In addition, this section provides the results of the qualitative NEB review. This section is organized as follows:

- Section 4.4.1—MASH Cost-Benefit Test Results (Without NEBs)
- Section 4.4.2—MASH Cost-Benefit Test Results (Modified to Include NEBs)
- Section 4.4.3—MASH Qualitative Non-Energy Benefits

[130] California Public Utilities Commission, Decision Adopting Cost-Benefit Methodology for Distributed Generation, August 20, 2009. http://docs.cpuc.ca.gov/word_pdf/FINAL_DECISION/105926.pdf.

4.4.1 MASH Cost-Benefit Test Results (Without NEBs)

The MASH cost-benefit test ratios were similar in value to the SASH results. One notable difference is the improvement in the PAC test, which was attributable to lower incentives as a percentage of the total system installation and equipment costs (relative to the SASH percentages). The tax and financing benefits helped offset the lower incentives (relative to the SASH percentages) and thus, the PCT cost-benefit ratios are similar to those seen in the SASH program.[131] Despite the lower MASH incentive percentages relative to SASH, the MASH RIM test did not increase with the PAC because lost revenues were higher on a levelized $/kWh basis compared with SASH. The higher lost revenues occurred because MASH customers (specifically building owners) were typically on rate structures with higher energy rates. Table 4-16 provides the MASH cost-benefit ratios without NEBs.[132]

Table 4-16. MASH Cost-Benefit Ratios without NEBs

Install Year	IOU	TRC	SCT	PAC	PCT	RIM
2011	PG&E	0.35	0.42	0.51	1.58	0.22
	SCE	0.33	0.40	0.53	1.43	0.23
	SDG&E	0.40	0.50	0.49	1.74	0.23
	Wtd. Avg.	0.36	0.44	0.57	1.53	0.24
2012	PG&E	0.35	0.42	0.58	1.48	0.24
	SCE	0.45	0.56	0.62	1.79	0.25
	SDG&E	0.39	0.47	0.55	1.49	0.26
	Wtd. Avg.	0.40	0.49	0.60	1.60	0.25
2013	PG&E	0.42	0.49	0.77	1.52	0.28
	SCE	0.40	0.47	0.73	1.45	0.29
	SDG&E	0.43	0.50	0.83	1.30	0.34
	Wtd. Avg.	0.40	0.49	0.53	1.63	0.25
Wtd. Avg.	**PG&E**	**0.35**	**0.43**	**0.51**	**1.55**	**0.23**
	SCE	**0.41**	**0.50**	**0.60**	**1.65**	**0.25**
	SDG&E	**0.41**	**0.48**	**0.75**	**1.47**	**0.28**
	Wtd. Avg.	**0.38**	**0.47**	**0.58**	**1.58**	**0.24**

Source: Navigant Consulting, Inc.

[131] The PCT for MASH includes costs and benefits for both tenants and owners.

[132] Here NEBs refers to the non-energy benefits that could be quantifiably estimated from the limited LIPPT-adapted tests.

Net benefits without NEBs for each of the cost tests appear in Table 4-17. In this scenario, participants can expect $53.8 million in net benefits over the PV systems' lifetimes, while ratepayers can expect $117.6 million in net costs.

Table 4-17. MASH Net Benefits without NEBs ($)

Install Year	IOU	TRC	SCT	PAC	PCT	RIM
2011	PG&E	-12,359,929	-12,160,137	-6,328,311	10,276,097	-23,252,984
	SCE	-10,310,611	-10,322,999	-4,538,370	6,244,219	-16,933,569
	SDG&E	-4,614,509	-4,134,931	-3,235,342	5,410,039	-10,378,718
	Total	-27,285,049	-26,618,068	-14,102,023	21,930,355	-50,565,272
2012	PG&E	-8,921,245	-8,958,017	-3,427,031	6,129,044	-15,033,256
	SCE	-12,031,382	-10,744,178	-6,118,857	16,370,457	-29,906,017
	SDG&E	-2,248,130	-2,156,368	-1,141,370	1,649,191	-4,044,566
	Total	-23,200,757	-21,858,563	-10,687,258	24,148,693	-48,983,839
2013	PG&E	-4,533,369	-4,471,360	-953,876	3,679,768	-8,445,837
	SCE	-5,131,273	-5,066,432	-1,271,545	3,721,006	-8,481,229
	SDG&E	-801,127	-797,569	-123,586	368,593	-1,146,607
	Total	-10,465,769	-10,335,361	-2,349,008	7,769,366	-18,073,673
Total	PG&E	-25,814,543	-25,589,514	-10,709,218	20,084,909	-46,732,077
	SCE	-27,473,266	-26,133,609	-11,928,772	26,335,682	-55,320,816
	SDG&E	-7,663,766	-7,088,869	-4,500,298	7,427,822	-15,569,891
	Total	-60,951,575	-58,811,992	-27,138,288	53,848,414	-117,622,784

Source: Navigant Consulting, Inc.

4.4.2 MASH Cost-Benefit Test Results (Modified to Include NEBs)

Navigant estimated NEBs for PG&E, SCE, and SDG&E for the MASH program. NEBs are benefits to the utility and benefits to participants. The MASH program analysis focused on benefits to MASH participant tenants under VNM because installing solar directly affects tenants' utility bills under VNM but not under the standard NEM tariff.

Navigant estimated first-year benefits and levelized benefits across a 20-year project period for projects installed in 2011, 2012, and 2013. In addition, the team estimated levelized benefits by utility for 2011 through 2013 weighted by the number of annual program participants (MASH VNM tenants). NEBs are comprised of two categories of benefits, utility benefits and participant benefits, with multiple types of benefits under each category.

Navigant estimated NEBs from the MASH program for VNM tenant projects by IOU. First-year benefits range in 2013 from $73 for SCE to $133 for SDG&E. The weighted average benefits by utility ranged from $101 for SCE to $115 for PG&E to $184 for SDG&E. Similar to the SASH program, the results differ by IOU because each utility has different average costs and bill impacts, which are the basis for the NEB calculations.

Table 4-18. NEBs by Utility per Participating Household for MASH VNM Projects

	1st Year NEBs ($)	Levelized NEBs ($)	Program Wtd. Avg. NEBs ($)
PG&E			
2011	72	112	115
2012	111	116	
2013	109	1175	
SCE			
2011	92	101	101
2012	79	100	
2013	73	101	
SDG&E			
2011	157	99	184
2012	141	184	
2013	133	185	

Note: Results rounded to the nearest dollar.

Source: Navigant Consulting, Inc.

Table 4-19 presents a breakdown of utility and participant NEBs by utility for MASH VNM projects installed in 2013. Similar to SASH, the results show that the avoided rate subsidy for CARE payments comprises a large portion of the NEBs for MASH VNM projects.

Table 4-19. Breakdown of Utility and Participant NEBs for MASH VNM Tenants (2013)

MASH VNM Tenant - Non-Energy Benefits (2013)	PG&E ($)	SCE ($)	SDG&E ($)
Utility Benefits			
Utility Rate Subsidy Avoided (CARE) Payments	75	55	99
Reduced Carrying Cost on Utility Arrearages	18	7	12
Utility Fewer Customer Calls	4	3	7
Utility Lower Bad Debt Written Off	1	1	3
Utility Fewer Notices	1	3	2
Utility Fewer Shutoffs	0	0	0
Utility Fewer Reconnects	0	0	0
Utility Reduced Collection Costs	0	0	0
Participant Benefits			
Participant Reduced Homelessness and Mobility	4	2	4
Participant Net Household Benefits from Additional Hardship Benefits	4	1	4
Participant Fewer Calls to Utility	1	0	1
Participant Fewer Shutoffs	1	1	1
Participant Fewer Reconnects	0	0	0
Participant Property Value Benefits	0	0	0
Total Benefits	**109**	**73**	**133**

Note: Results rounded to the nearest dollar.

Source: Navigant Consulting, Inc.

Table 4-20 shows the cost-benefit ratios with NEBs. The inclusion of NEBs increased the cost-benefit ratios by 15 percent for the TRC, 11 percent for the SCT, 13 percent for the PAC and RIM, and a negligible amount for the PCT. The PCT's smaller increase reflects that participants only receive about eight percent of the total value of NEBs, while the IOUs receive the remaining 92 percent (on a levelized $/participant-year basis). More generally, NEBs have a smaller impact on MASH cost-effectiveness compared with SASH because the tenants' percentage of total energy savings is 34 percent (with owners receiving 66 percent) and, therefore, NEBs are applicable to a smaller portion of the participants.

Table 4-20. MASH Cost-Benefit Ratios with Inclusion of NEBs

Install Year	IOU	TRC	SCT	PAC	PCT	RIM
2011	PG&E	0.41	0.48	0.59	1.58	0.26
	SCE	0.34	0.41	0.54	1.43	0.24
	SDG&E	0.55	0.64	0.66	1.76	0.31
	Wtd. Avg.	0.41	0.48	0.59	1.56	0.26
2012	PG&E	0.42	0.48	0.69	1.48	0.28
	SCE	0.47	0.57	0.64	1.79	0.26
	SDG&E	0.53	0.60	0.74	1.51	0.35
	Wtd. Avg.	0.46	0.54	0.67	1.66	0.27
2013	PG&E	0.47	0.54	0.87	1.53	0.31
	SCE	0.46	0.53	0.84	1.45	0.33
	SDG&E	0.61	0.66	1.16	1.31	0.48
	Wtd. Avg.	0.48	0.55	0.88	1.47	0.33
Wtd. Avg.	**PG&E**	**0.42**	**0.49**	**0.66**	**1.54**	**0.27**
	SCE	**0.42**	**0.51**	**0.64**	**1.60**	**0.26**
	SDG&E	**0.55**	**0.63**	**0.71**	**1.65**	**0.33**
	Wtd. Avg.	**0.44**	**0.52**	**0.66**	**1.58**	**0.28**

Source: Navigant Consulting, Inc.

After including NEBs in the cost tests, net benefits improved by nine percent for the TRC, 10 percent for the SCT, 19 percent for the UCT, one percent for the PCT, and four percent for the RIM. Table 4-21 shows that NEBs increase net benefits to $54.4 million for participants and decrease net costs to $112.5 million for the ratepayers.

Table 4-21. MASH Net Benefits with Inclusion of NEBs ($)

Install Year	IOU	TRC	SCT	PAC	PCT	RIM
2011	PG&E	-11,227,525	-11,027,733	-5,315,089	10,395,280	-22,239,763
	SCE	-10,128,752	-10,141,140	-4,369,463	6,257,171	-16,764,662
	SDG&E	-3,453,826	-2,974,248	-2,175,459	5,510,839	-9,318,835
	Total	-24,810,103	-24,143,121	-11,860,011	22,163,290	-48,323,260
2012	PG&E	-7,986,522	-8,023,294	-2,590,418	6,227,154	-14,196,642
	SCE	-11,615,275	-10,328,071	-5,732,300	16,400,008	-29,519,461
	SDG&E	-1,732,164	-1,640,401	-669,965	1,693,753	-3,573,161
	Total	-21,333,961	-19,991,767	-8,992,683	24,320,914	-47,289,264
2013	PG&E	-4,080,937	-4,018,928	-548,681	3,727,004	-8,040,642
	SCE	-4,569,663	-4,504,821	-749,780	3,760,850	-7,959,464
	SDG&E	-543,283	-539,726	112,057	390,794	-910,964
	Total	-9,193,883	-9,063,476	-1,186,404	7,878,648	-16,911,070
Total	**PG&E**	**-23,294,984**	**-23,069,956**	**-8,454,188**	**20,349,437**	**-44,477,047**
	SCE	**-26,313,690**	**-24,974,032**	**-10,851,543**	**26,418,029**	**-54,243,587**
	SDG&E	**-5,729,273**	**-5,154,375**	**-2,733,367**	**7,595,385**	**-13,802,960**
	Total	**-55,337,947**	**-53,198,363**	**-22,039,098**	**54,362,852**	**-112,523,594**

Source: Navigant Consulting, Inc.

4.4.3 MASH Qualitative Non-Energy Benefits

Navigant conducted a qualitative assessment of NEBs to supplement the top-down quantitative analysis done through the LIPPT model. Because the LIPPT model addresses benefits of low-income energy efficiency programs, the approach includes some, but probably not all, of the benefits that might reasonably apply to a low-income solar program.

To identify additional NEBs for the MASH program, Navigant leveraged in-depth interviews and participant surveys from the Market and Program Administrator Assessment[133] to gather market actor input on the scope and scale of likely program-related NEBs and costs. Navigant conducted focused

[133] Navigant Consulting, Inc. "California Solar Initiative—Biennial Evaluation Studies for the Single-Family Affordable Solar Homes (SASH) and Multifamily Affordable Solar Housing (MASH) Low-Income Programs: Market and Program Administrator Assessment, Program Years 2011–2013." Prepared for the California Public Utilities Commission.

meetings with the PAs and the SASH/MASH M&E Team to discuss and prioritize the NEB topics used in subsequent interviews and surveys.
Due to budget constraints, the team did not expect this limited inquiry to result in robust or comprehensive estimates of solar-specific NEBs. Instead, the results are intended to provide initial, qualitative information to guide future evaluations' prioritization and development of more defensible estimates of those non-energy elements.

Beyond energy bill savings for MASH property owners and VNM tenants, the MASH program provides additional NEBs to property owners and tenants, solar installers, and the community. The Navigant team asked VNM tenants about NEBs as part of the survey of 73 MASH tenants. The team also interviewed program market actors, including CPUC staff, MASH PAs, and MASH installers by asking them to describe the NEBs of the MASH program. Similar to SASH, this research indicated that NEBs create additional value to the MASH program.

4.4.3.1 Tenant Perspective

Navigant asked MASH VNM tenants what benefits they noticed from the MASH program and the installation of solar. The results in Table 4-22 show that many tenants consider financial benefits such as lower energy bills (36 percent). Secondly, 14 percent of the tenants cited environmental benefits as a benefit of solar. Tenants also cited learning opportunities for their children and pride in their building (one percent each) as benefits of the program.

Table 4-22. Tenant Benefits from the MASH Program

Survey Question: Aside from energy cost savings, have you noticed other benefits resulting from the MASH program and the installation of solar? How do you think the program has benefitted you personally?	
Response	**Percent**
Lower energy bills*	36
Environmental benefits/going green/reducing pollution	14
Learning opportunity for kids	1
Pride in our building	1
Other specified	4
No benefits	42
Don't know	7

Note: Respondents could provide more than one response, so total does not sum to 100%.
*It appears that many survey respondents essentially provided the answer that the question asked to leave out. However, the distribution of the rest of the responses gives an idea of the respondents' other perceived benefits of the program.
Source: MASH tenant survey, 2014 (n=73)

When asked to describe these benefits further, additional benefits mentioned by tenants included the following:

- More money for their children
- Help with family budgets
- Reduced payments after signing up for the CARE program
- Able to go shopping for clothing with the money saved

When the research team asked tenants how the MASH program has benefitted the community and the economy, more than half (59 percent) said that the program gave them more money to spend on other things. Other benefits included job creation for solar installers (23 percent) and the opportunity for education and building awareness (15 percent).

4.4.3.2 Market Actor Perspective

Navigant asked program market actors about potential NEBs of the MASH program as part of the in-depth interviews for the Market and Program Administrator Assessment. The research team first asked the respondents to describe the benefits of the MASH program beyond energy savings. The team then asked how the MASH program benefitted specific entities such as the environment, the individual respondent, the electric grid, low-income homeowners and communities, the utility, and the economy.

Respondents found the NEBs, although sometimes difficult to quantify, an important aspect of the programs benefits. The most common NEB mentioned across MASH market actors was an improvement in tenant lifestyle. Other NEBs mentioned by one or two respondents included job training, education and energy consumption awareness, reduced vacancy rates, environmental benefits, reduced stress on the electric grid, and improved reliability. This section summarizes the NEBs described in the interviews.

- **Environmental benefits:** Interviewees overwhelmingly agreed that solar has a positive impact on the environment by reducing fossil fuel use and thereby reducing carbon emissions. As one MASH installer explained, "The most critical and obvious [environmental benefit] is reducing the discharge of toxic climate-disrupting greenhouse gasses (CO_2 and methane) into the atmosphere. Air and water quality is improved, since there are no solar spills and no solar pollution of groundwater, lakes, and streams, all of which will be polluted by fossil fuels, both directly and indirectly (through airborne pollutants)." Others equated the benefits to planting trees and eliminating the need for more power plants.
- **Benefits to MASH installers:** MASH installers explained that the program has benefitted them by providing additional work. One installer described how the MASH program has made solar sufficiently affordable to non-profit customers and helped the installers create a niche market that is focused exclusively on affordable housing. The installer added that the MASH incentives have helped projects move forward that would not have been possible without the rebate. Other installers mentioned that the program has helped installers establish a track record in solar and has helped keep them busy during slow times. As one installer put it, "It helps people get out there working. I can hire new people; I can maintain the people I have. I can give a certain amount of people the

opportunity to come in and learn about solar." Overall, MASH installers had very positive things to say about the program and the impact it has had on their businesses.

- **Tenant economic benefits:** Respondents believe that the MASH program benefits low-income communities by reducing energy bills, which enables property owners to spend the energy bill savings on facility improvements. One MASH installer explained, "We have seen housing developers … add recreation rooms, computer training, vocational education, plus many property enhancements for the enjoyment and use of their low-income tenants due at least in part to their solar savings." One respondent explained that the MASH program is important to affordable housing communities because it stabilizes affordable housing by eliminating the uncertainty of energy costs.
- **Community economic benefits:** Market actors believe that the MASH program has benefitted the economy by providing local jobs and training, and it provides utility bill savings that low-income tenants can spend elsewhere in the community. As one MASH installer explained, "Money saved on energy will be spent locally, whereas money spent on utility bills leaves the community and flows to large corporations and their shareholders." Additionally, market actors believe that communities have pride and satisfaction knowing that their energy is clean and green.
- **Utility benefits:** Similar to SASH, respondents opinions differed regarding whether solar installed through the MASH program benefitted or harmed the utility. Some mentioned utility benefits such as not needing to build as many power plants, reducing maintenance expenses, improving grid reliability, and reducing peak demand. However, others believed that solar is a threat to the utility business model. A MASH installer explained that the "pushback from the utilities is that they have some concerns about what effects it will have on their income stream over time."

4.4.3.3 Most Significant MASH Benefits

MASH tenants and other market actors agree that reducing utility bills and benefits to the environment were the two most important MASH program benefits. Multiple respondents also indicated that improving quality of life in low-income communities and boosting employment were the most important aspects of the program. The MASH program benefit responses were similar to the benefits described for the SASH program.

5 Recommendations

The purpose of this section is to outline recommendations based on the 2011–2013 impact and cost-benefit analysis. The recommendations focus on opportunities to improve the implementation of the SASH and MASH programs by the PAs and to facilitate more robust and transparent oversight of the programs in the future. The following list contains three program-related recommendations that came out of the impacts and cost-benefit analyses.

- **Conduct a detailed, bottom-up analysis of the NEBs of the SASH and MASH programs.** One of the goals of the extended SASH and MASH programs is to maximize benefits to ratepayers.[134] The current NEB analysis is limited in scope and was adapted from a model that is not specific to PV solar programs; thus, the results are illustrative rather than comprehensive. A quantitative, in-depth understanding of NEBs of the SASH and MASH programs would allow the CPUC to properly assess and attribute relevant benefits to the ratepayers, thus enabling better evaluation of the extended programs' progress toward meeting their stated goals.

  The analysis would first include a review of the literature and in-depth interviews with subject matter experts to confirm the categories of NEBs that are associated with low-income distributed generation programs. The team would then develop a methodology and modeling framework for organizing and estimating NEBs. Finally, the team would conduct primary and secondary research to derive IOU-specific, program-induced benefits for each of the NEBs categories. It is envisioned that the research would include a data request to obtain utility and program-specific information from each of the IOUs and a survey of SASH and MASH participants.

- **Implement a long-term strategy for supporting SASH inverters after the current 10-year warranty period [Applicable to SASH only].** GRID Alternatives currently meets the program requirements for a CSI standard 10-year warranty. However, because the PV modules will outlast the inverters and SASH customers may not have the means to replace them, it is important to plan for the eventuality of a certain percentage of inverter replacements each year. The stated goal of the SASH program is to decrease electricity usage by solar installation and to reduce energy bills without increasing monthly expenses. Even though GRID Alternatives currently provides training to SASH participants on how to save for eventual O&M costs, it is likely that many SASH customers will have difficulty paying for the replacement inverters (in the event of inverter failure)—especially with higher monthly energy costs due to the failed PV system. By revising program goals to include a long-term strategy for supporting the replacement of SASH inverters after 10 years, the SASH program would be able to maintain the reduced electricity bills for customers over a longer time horizon.

- **The CPUC should work with the PAs to ensure consistent and accurate installation and field inspection procedures.** This recommendation stems from two evaluation findings—the first from

[134] AB 217 states this goal. The full text of AB 217, Chapter 609 may be found here: http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB217.

the field verification visits and the second from the desk review. Each finding and a related recommendation appears below.

- **A high number of azimuth angle discrepancies uncovered in the field are greater than 10 degrees from the tracking database-reported values.** Out of the 14 MASH arrays verified via site visits, six had azimuth discrepancies greater than five degrees, the threshold requiring re-calculation of design factor. At the SASH sites, five out of eight arrays had discrepancies greater than five degrees. Many of the discrepancies for both programs were greater than 10 degrees, signifying a need for further training for inspectors and/or installers, particularly around magnetic declination and proper calculation of true array azimuth. While azimuth discrepancies do not have a large impact on design factor, record accuracy and quality control are still important. According to AB 217, one of the goals of the SASH and MASH programs is to provide job training and employment opportunities in the solar energy and energy efficiency sectors of the economy. Adding in-service training for inspectors and lead installers around properly determining system characteristics would improve their skillsets and professionalism. The CPUC should consider working with the PAs to provide training for lead installers and inspectors around consistent PV characteristic reporting.
- **Inspection policies should be consistent across PAs [Applicable to MASH only].** Currently, third-party inspectors at PG&E sites verify only a subset of arrays at sites with more than about 30 arrays. The inspectors for SCE and CSE typically verify all arrays onsite. Navigant recommends either verifying all arrays or at least verifying array capacity. The justification for this recommendation comes from a program goal stated in the MASH handbook:

  > *"Program Administrators will conduct a system inspection visit for each Incentive Form submitted to verify that the project is installed as represented in the application. . ."*

  Developing a consistent policy for how to treat inspections at sites with a large number of arrays will serve MASH program goals by improving the inspection quality and making it consistent across all PAs. The most robust policy for third-party inspections would be to require 100 percent inspection of all arrays at MASH sites. At minimum, inspectors should verify the total quantity and nameplate rating of those arrays that are not included in the full verification, if sampling is required for budgetary reasons.

In addition to the program-specific recommendations above, there were a number of recommendations regarding data quality and accessibility encountered during the course of the evaluation. In January 2015, the impact team wrote a memo summarizing data quality issues encountered and provided recommendations for how to address them. Appendix A contains the memo. The main recommendations from that memo appear at the beginning of Appendix A, along with several other data-related recommendations that the team discovered after finalizing the memo.

Appendix A Data Quality Recommendations

This appendix outlines several recommendations stemming from data issues encountered during the evaluation. While these recommendations may not necessarily improve program performance, they would improve the efficiency and effectiveness of the evaluation process.

A.1 DATA QUALITY RECOMMENDATIONS

SASH and MASH

- **Implement a version control strategy that tracks PV system characteristics through the installation/QC/third-party inspection process.** When multiple versions of program documentation files exist (such as EPBB printouts and third-party inspection worksheets), PAs need to be able to document clearly which files are current and which are no longer relevant. This will improve transparency for program evaluators and help reduce clerical errors.

SASH Only

- **Store all participant PV system characteristics from third-party verification forms and EPBBs in Salesforce in tabular format rather than as PDF, HTML, or JPEG files.** Instead of scanning and uploading PDF inspection files, the evaluation would benefit from installers/third-party inspectors entering PV system characteristics into a database similar to the way it is done for MASH. This would drastically reduce evaluation budget spent scraping PV system characteristics from PDF files and preparing PV production model input files.

MASH Only

- **Create a robust data map for the PowerClerk system.** From an evaluation standpoint, the content of the PowerClerk database is not transparent and understanding the system required a significant time investment because of the following:
    1. There is no comprehensive list of variables currently tracked in the PowerClerk system.
    2. There are a large number of existing reports in the database but no way to see their contents without downloading and opening each one.
    3. The system gave errors when trying to export some larger reports.

  A data map showing what variables PowerClerk tracks along with definitions downloadable from PowerClerk would make the data management more transparent and facilitate audits/evaluations by third parties, increasing time that could be spent on other parts of the evaluation.
- **Explicitly track each VNM generating meter number associated with each relevant MASH application ID.** The VNM metered data provided by the PAs did not come with a MASH application ID. Even after a follow-up request with PAs, the evaluation team was only able to

match VNM data for some MASH sites. This could be avoided if VNM meter numbers associated with the metered data were tracked in the PowerClerk database. Ideally, VNM account numbers should be tracked at the array level. Doing so would improve the impact evaluation by allowing a greater percentage of the VNM data to be used during the calibration.

- **Track tenant/owner benefit allocation data in PowerClerk, including meter number, account number, address, and percent allotment.** Currently, allocation data exists in various formats. Having that data stored electronically in the database would allow evaluators to better understand PV allocations, and it would make the bill impact model more accurate.
- **Track any housing assistance for participants at the application ID level.** In order to properly attribute costs and benefits of the MASH program, an evaluator needs to know housing assistance status for MASH project tenants (e.g., Housing and Urban Development [HUD] or Tax Credit Assistance). This data is not currently tracked in the PowerClerk database; doing so would make the cost-benefit analysis more accurate.

A.2 DATA QUALITY MEMO

Navigant sent the following memo to the CPUC on January 15, 2015. It has been modified slightly to better coexist with the formatting of the rest of this report. The memo is provided in its original form below even though some of the recommendations have since been revised. Please refer to Section A.1 for a list of the most up-to-date data quality recommendations.

Memorandum

To: Shannon O'Rourke (CPUC)

From: Pace Goodman, James Milford, Vergil Weatherford, Eric Merkt, Beth Davis (Navigant Consulting)

Date: January 15, 2015

Re: Impact Evaluation Recommendations: Current Data Quality Issues

In this memo, Navigant outlines recommendations to streamline and improve the accuracy of future impact evaluations for the CPUC's California Solar Initiative (CSI) Single-Family Affordable Solar Homes (SASH) program and the Multifamily Affordable Solar Housing (MASH) program. Navigant is still in the process of completing the evaluation; therefore, these recommendations are from the work completed to date. Navigant will include any additional findings and recommendations in the final reports for this evaluation.

Findings and Recommendations

As of January 15, 2015, Navigant uncovered several data concerns in evaluating these programs. While the concerns identified have required additional effort for this evaluation, Navigant believes the PAs can improve these issues for the next cycle's evaluation. The following recommendations are the highest priority:

1. Create a robust data map for the PowerClerk system[135]
2. Store all participant PV system characteristics from third-party verification forms and EPBBs in database format rather than as PDF, HTML or JPEG files
3. Explicitly track each virtual net energy metering (VNM) generating meter number associated with each relevant MASH application ID
4. Track any housing assistance for participants at the application ID level
5. Track information about gap funding

[135] Navigant recommends using the data map to identify opportunities to improve program design and data collection processes in addition to facilitating improved evaluation.

Table A-1 contains all recommendations to date and connects all recommendations to Navigant's current findings. Recommendations are numbered 1-8 and are described in more detail in the next section.

Table A-1. Navigant's Interim Data Issue Findings and Recommendations

Impact Evaluation Process	Interim Finding	Recommendation	Relevant Audience for Recommendation
Overall	Sorting through all PowerClerk reports to fully understand the available data requires significant effort	1. Develop a data dictionary for the PowerClerk system. This dictionary may help inform future data collection process changes	Utilities: All Program: MASH
Energy Generation	Third-party verification forms and EPBB printouts are stored as various non-consistent PDF, HTML, and JPEG formats	2. Store all as-installed and verified PV characteristics data in a database rather than as individual PDF/HTML/JPEG files. This will eliminate the time required to scrape the PDFs for data such as monthly shading values, and tilt/azimuth	Utilities: All Programs: SASH & MASH
	Duplicate EPBB printouts exist for some arrays with conflicting information. Also, there is a high clerical error rate between Salesforce and EPBB for DF	3. Implement a version control strategy which tracks PV system characteristics through the installation/QC/3rd party inspection process	Utilities: All Programs: SASH & MASH
	Third-party inspector only verifies a small subset of arrays at sites with more than ~30 arrays due to onsite sampling	4. Verify at least the total installed nameplate wattage at all arrays at all sites. If sampling is necessary, third-party inspectors should prioritize arrays that do not meet the minimum shading requirement	Utilities: PG&E Program: MASH
	60% (34% prior to the Phase 2 Data Request) of relevant sites from PowerClerk merge with VNM energy generation data[136]	5. Explicitly track each VNM generating meter number associated with each application ID in the PowerClerk database	Utilities: SCE and SDG&E Program: MASH (VNM only)
First-Year Bill Reduction	59% of a 39 site sample contains consistent data between PowerClerk and paper allocation forms	6. Implement a QC protocol to ensure this data is accurately stored in PowerClerk	Utilities: All Program: MASH (VNM only)
Cost-Benefit Analysis	The program does not currently track the housing assistance status (e.g., HUD assisted) of low-income projects	7. Track any government/housing assistance for participants at the application ID level	Utilities: All Program: SASH & MASH
	The programs do not accurately track gap funding between program expenses and full installation costs	8. Track information about gap funding, eliminating participant self-reporting bias if possible	Utilities: All Program: SASH & MASH

Details
This section outlines the data requirements for the impact evaluation, including the cost-effectiveness evaluation, and it details the recommendations to improve data quality.

Data Requirements
The impact evaluation process for the SASH and MASH programs requires data inputs from each of the PAs. Those data inputs feed into the analysis to support a number of tasks central to the impact analysis:

- Verify field characteristics of a sample of participant sites
- Estimate hourly energy generation from participant PV installations
- Estimate first-year participant bill reduction
- Calculate the following benefit cost tests:
    - Low-Income Public Purpose Test (LIPPT)
    - Participant Cost Test (PCT)
    - Utility/PA Cost Test (PACT)
    - TRC (including the SCT)

[136] Navigant will provide results comparing VNM generation data to SAM generation estimates in the final report. Navigant expects that some sites may not match due to merging issues—e.g. where too few or too many generating meters merge with the participant data.

The SASH and MASH program PAs currently collect most of the data necessary to conduct the evaluation analysis, but some of it is stored in such a way that considerable effort is required to leverage that data. Table A-2 describes the most important data required to carry out the impact evaluation.

Table A-2. Data Requirements for Impact Evaluation Processes

Impact Evaluation Process	Data Source	Purpose	Key Links Between Datasets
Energy Generation	PV Array System Characteristics	Estimate energy generation for TMY and actual historic conditions using SAM[137]	Application ID, Generation Meter Number (VNM MASH sites only) and Array ID
	Generation Data (VNM)	Ensure accuracy of SAM models for MASH sites	Application ID and Generation Meter Number
First-Year Bill Reduction	Electronic Rate Structure Data	Estimate potential bill reduction from solar generation	Rate Class, Month, Year and (if possible) Application ID
	Customer Rate Class Data	Apply potential bill reduction for each customer to the estimated solar generation	Application ID
	Tenant/ Owner Split	Distribute energy benefits between owners and tenants	Application ID
Cost-Benefit Analysis	Residential Rate Forecasts	Estimate participant benefits over the effective useful of the system	Year, Utility and (if possible) Rate Class
	Housing Assistance Status (e.g., HUD or Tax Credit Assisted)	Estimate appropriate tenant and owner benefits[138]	MASH Application ID
	Discount Rates	Normalize future benefits to the current dollar	Utility and Cost Test
	System Installation Costs	Estimate societal and participant costs	Application ID
	Gap Funding	Estimate actual costs incurred by participants [139]	Application ID
	Incentive Levels	Estimate utility and participant costs	Year Utility, Program
	Administrative Expenditures	Estimate societal and utility costs	Year, Utility, Program

[137] SAM is a piece of modeling software produced by the National Renewable Energy Laboratory that has the ability to accurately model 8,760 hourly production of PV arrays.
[138] Certain assistance programs calculate utility bills based on income rather than consumption. In these instances, participants may not see the entire benefit (if any) from the PV generation.
[139] GRID obtained additional funding for certain participants through a variety of sources, such as foundation grants and volunteer labor from citizens interested in renewable energy. In these cases, the participants paid for only part of the difference between the utility incentive and the installation cost.

Recommendations to Improve Data Quality

The team has detailed the recommendations listed in Table A-1 in this section. The numbering of the recommendation in Table A-1 matches the numbering of each subheading below.

1. *Develop a data map for the PowerClerk system*

Navigant recommends developing a data map for the PowerClerk system that:

- Provides the PowerClerk location of any relevant data points presented in Table A-2
- Identifies and describes version control processes
- Identifies the intended link between data collected through the various stages of the program

Evaluating the MASH program introduces additional considerations beyond the SASH program evaluation, such as larger system size, benefit allocation to tenants versus owners and accounting for the complexity of multiple utility accounts a single participant application. While the existing "PowerClerk glossary" document effectively defines each parameter, it does not describe the flow of data or provide adequate information to correct or better understand inconsistencies. This map can also serve to inform potential program and data collection process improvements.

2. *Store all as-installed and verified PV characteristics data in a database*

To verify the program benefits, Navigant estimates site-level energy generation by inputting program PV characteristics into NREL's SAM. For the MASH program, Navigant was able to access some of the PV characteristics from the PowerClerk data system, including PV and inverter quantity and nameplate information, array tilt and azimuth. Notably missing are monthly shading values and PV standoff height, both necessary for more accurate modeling. For the SASH program, the only data included in the Salesforce database are the quantity, make, and model of the PV modules and inverters as well as the total nameplate power rating.

For both programs, in order to fill in missing data required for modeling, Navigant custom-coded computer programming tools to scrape PV characteristics from third-party inspection forms and EPBB data stored as PDFs. Aside from being time consuming, there are several issues with this approach. This tool cannot scrape data from JPEG files nor non-standardized PDF files (such as files saved in other formats and then converted to PDF). In addition, merging scraped data with the program databases (PowerClerk and Salesforce) is inexact and relies on fuzzy matching algorithms, which produces some false matches. As of the date of this memo, the impact evaluation team is able to model PV generation at approximately 70 percent of MASH sites with relative confidence. See Addendum C for more detail. Scraping and merging is still underway with the SASH data, but a preliminary estimate is that roughly 50 percent of SASH sites will be able to be modeled with relative confidence. These numbers could improve as the team refines the scraping/matching algorithms.

Storing data from third-party inspection forms and EPBBs in a database format rather than PDF or JPEG will enable the evaluator to verify savings at a greater number of sites and will reduce the evaluation costs. One potential way to collect this data would be to have the EPBB calculator capture and store all inputs, providing a unique reference number for each run that could be used to match program databases with the stored array characteristics. Third-party MASH inspectors could use a unified form (such as a centrally developed smartphone/tablet app) for onsite data collection, storing as-inspected PV characteristics in a central database.

3. *Implement version control for arrays with multiple EPBB*

Navigant encountered some individual arrays with multiple EPBB printouts. The program may need to store multiple files for a given site to ensure accurate and up-to-date data, but the PAs should implement a version control strategy to ensure the evaluator uses the correct data in their analysis. This version control strategy should tie a date and version status to all data collected in the EPBB files.

Additionally, six SASH sites of a randomly selected sample of 10 had clerical errors associated with transferring the DF over to the Salesforce database. This could be corrected by storing the data in a database and implementing version control for multiple EPBBs for an individual array. The data storage solutions proposed in recommendation #2 would largely prevent this kind of issue.

4. *Verify total installed name plate wattage at sites with array sampling*

Navigant found that third-party evaluators did not collect PV characteristics for all arrays at the largest five MASH PG&E sites (30+ arrays). Without this information, Navigant cannot properly model energy generation at these sites (key model inputs are missing).

If it is not feasible to completely verify the arrays at a site, Navigant recommends that third-party inspectors continue to collect full PV system characteristics data for a sample of the arrays at these sites, but additionally verify the nameplate wattage and module quantity for all arrays at these sites. Additionally, the sample should include all arrays that do not meet the minimum shading threshold.

5. *Explicitly track all VNM generating meter numbers associated with each application ID*

Navigant recommends explicitly tracking in PowerClerk each VNM generating meter number associated with each application ID (separate from energy usage meter numbers) to increase the ease with which VNM data can be matched with program data. It is currently unclear how the account number associated with the VNM generation data links to participant account numbers (it could link through the property owner, certain tenants, etc.), but it appears the meter numbers associated with the VNM generation data do not correspond to specific consumption meter numbers.

Following the Phase 1 data request, Navigant was able to merge 34 percent of the 94 relevant VNM sites with VNM generation data. Following the Phase 2 data request, Navigant was able to merge 60 percent of the relevant sites with generation data. Navigant presents these findings in detail in Addendum A. Furthermore, Navigant expects there may be additional merging issues and will present results comparing the VNM generation data to the SAM-estimated energy generation in the final report.

6. *Improve QC protocol for allocation forms*

Navigant was unable to verify the allocation percentages for 41 percent of a randomly selected 39 MASH VNM sites. Navigant was not able to obtain any allocation forms from SCE, which accounts for 23 percent of the sample, and another 18 percent of discrepancies occurred for PG&E and SDG&E sites. As a result, Navigant recommends all PAs implement a QC protocol to ensure that the allocation data stored in PowerClerk is accurate and up-to-date.

These findings are presented in more detail in Addendum B.

7. Track MASH project housing assistance status (e.g., HUD assisted)

Navigant recommends tracking the type of government assistance associated with each MASH low-income participant application ID to improve the accuracy of the PCT. Future evaluators could use this information in combination with surveys to determine whether and to what extent the CSI program benefits go to tenants, property owners and existing government programs that are already supplementing low-income families.[140]

8. Track gap funding

Navigant recommends accurately tracking non-program funding, or gap funding, by application ID as a separate field in the database to improve the robustness of the cost-benefit analysis. The PCT requires an estimate of the actual costs incurred by the participant after rebate incentives and any additional funding. Data collection for gap funding for MASH was not consistent across IOUs, and applicants may have a disincentive to report outside gap funding if it will reduce MASH incentive allocations. On the SASH side, GRID often met the balance between SASH installation costs and the rebate incentive with grant funds, which reduced participant costs and improved the benefit/ cost ratio, but this data was not tracked or documented. Furthermore, this issue will be more important in the next phase of the program due to the reduced incentive amount for SASH projects under AB 217 and the likelihood of increased reliance on gap funding.

Addendum A: Merging Results for PowerClerk to VNM Energy Generation Data

Navigant merged VNM generation data with data stored in PowerClerk for the relevant MASH participants. The PG&E data merged through application ID, the SCE data merged through billing data (where application ID was tied to account number) and the SDG&E data merged through address. The first three rows in each table below provide site counts going into the merge and the merge results without filtering for participants relevant to this evaluation. The following three rows in each table below show those same results, but after filtering for participants specific to this evaluation.

Utility	Parameter	VNM Metered Generation	PowerClerk Database
PG&E	Unfiltered Count	54 Application IDs	895 Application IDs
	Unfiltered Merge	54 Application IDs	
	Unmerged	0	N/A
	Filtered Counts	54 Application IDs	43 Application IDs
	Filtered Merge	36 Application IDs	
	Unmerged	18 – 3 with statuses other than 'Completed', 7 with completed dates in 2010, 6 with completed dates in 2014, and 2 NEM sites	7 – unknown reasons

[140] CSI program benefits may offset or add to funding from other low-income programs, like the HUD and the Public Housing Authority, for MASH tenants that are allocated some percentage of the generated energy.

Utility	Parameter	VNM Metered Generation	PowerClerk Database
SCE	Unfiltered Count	121 Account Numbers	895 Application IDs
	Unfiltered Merge	6 Application IDs	
	Unmerged	84 Account Numbers	N/A
	Filtered Counts	6 Application IDs	22 Application IDs
	Filtered Merge	5 Application IDs	
	Unmerged	1 – completed date in 2014	17 – unknown reasons

Utility	Parameter	VNM Metered Generation	PowerClerk Database
SDG&E	Unfiltered Count	140 Account Numbers	895 Application IDs
	Unfiltered Merge	17 Application IDs	
	Unmerged	102 Account Numbers	N/A
	Filtered Counts	17 Application IDs	29 Application IDs
	Filtered Merge	15 Application IDs	
	Unmerged	2 – completed dates in 2010	14 – unknown reasons

Addendum B: Discrepancy results comparing PowerClerk to PDF stored allocation forms

Navigant compared the scanned paper allocation forms to the PowerClerk data for a randomly selected sample of MASH VNM sites. The number of randomly selected sites per utility was based on participation by each utility. Navigant categorizes sites as follows:

- **Missing Allocation Form:** Navigant was not able to locate the allocation form for the randomly selected site ID
- **Inconsistent Allocations:** Navigant was not able to match the allocations between the scanned allocation forms and PowerClerk
- **Available and Consistent Allocations:** Navigant successfully matched the allocations between the scanned allocation forms and PowerClerk

TOTAL	# of Application IDs	% of Sample
Sample Size	39	100%
Missing Allocation Forms	12	31%
Inconsistent Allocations	4	10%
Available and Consistent Allocations	23	59%

PG&E	# of Application IDs	% of Sample
Sample Size	18	100%
Missing Allocation Forms	3	17%
Inconsistent Allocations	2[141]	11%
Available and Consistent Allocations	13	72%

[141] The PowerClerk data for one site differs from the allocation form by less than one percent.

SCE[142]	# of Application IDs	% of Sample
Sample Size	9	100%
Missing Allocation Forms	9	100%
Inconsistent Allocations	0	0%
Available and Consistent Allocations	0	0%

SDG&E	# of Application IDs	% of Sample
Sample Size	12	100%
Missing Allocation Forms	0	0%
Inconsistent Allocations	2[143]	17%
Available and Consistent Allocations	10	83%

Addendum C: Coverage of modeled MASH Sites[144]

The following two tables show the outcome of having to scrape PV installation characteristics data out of files of varying formats, yielding an incomplete set of inputs for the hourly model. If the data were stored in database format, modeling coverage would be 100 percent for all sites. SASH sites were not yet modeled as of the date of this memo so are not included. Coverage of less than about 95 percent is usually caused by one or more arrays not getting scraped. Above about 95 percent, non-100 percent coverage is typically caused by clerical errors between third-party inspection forms and PowerClerk. Sites found to have 95 percent coverage or greater were included in the hourly modeling, while sites with less than 95 percent will have 8,760 hourly shapes estimated by extrapolation using other arrays within the same climate zone.

Modeling Coverage by Capacity	# of Application IDs	% of Population
0%	41	15.8%
>0% - 50%	14	5.4%
>50% -80%	12	4.6%
>80% - 90%	3	1.2%
>90% - 95%	0	0.0%
>95% - 99.9%	12	4.6%
100%	178	68%
Total	**260**	**100.0%**

[142] Navigant requested this data in Phase 1, and Eric Merkt received this data from both PG&E and CSE.

[143] Seemingly duplicate sites (MASH 00041, 00046) use different allocation forms that do not clearly differentiate between tenant and owner meter allocations.

[144] Coverage percentage Sum of the modeled PTC capacity (in kW) divided by the PowerClerk-recorded capacity for the same sites

This table shows results by PA:

PA	Modeling Coverage by Capacity	# of Application IDs	% of PA Applications	% of Population
PG&E	<95% >=95%	15 97	13.4% 86.6%	5.8% 37.3%
SCE	<95% >=95%	44 71	38.3% 61.7%	16.9% 27.3%
SDG&E	<95% >=95%	11 22	33.3% 66.7%	4.2% 8.5%
	Total	**260**		**100.0%**

Appendix B Field Data Collection Protocol

This appendix contains the field data collection protocol followed by the field technicians. As this is a document describing what steps the field technicians should take, it is in the future tense.

B.1 SCHEDULING AN INSPECTION

The Navigant (NCI) team carries out recruiting and scheduling. The NCI scheduler uses the online data entry system and a pre-approved script to recruit customers from the sample.

Each site will have a designated host who has agreed to be at the house during the time of the site visit. This may or may not be the same person who applied for the SASH or MASH incentive. It is highly recommended, but not required, that the applicant attend the inspection. *If neither the host nor the applicant is present for the site visit, the field crew will* ***not*** *conduct the inspection unless permission was previously obtained in writing or via e-mail allowing the site visit to take place without the host or the applicant present.*

Preferential Scheduling
Because of the nature of the measurements being taken by field crews, the sun must be at a high angle to the PV array (i.e., nearly directly overhead, not a glancing angle) at the time of the site visit. In order to facilitate this condition, the scheduling database will include a preferential scheduling time of day (morning, midday, afternoon). If someone from the household is not available during a preferential time, the scheduler can go ahead and schedule the visit outside the preferential time, making a note in the online system to that effect.

The scheduler will also provide call-aheads, calling customers the day before their site visit to confirm the date and time.

B.2 PRIOR TO GOING ONSITE

Step 1: Log into the Data Entry System and Look at Scheduled Sites
The first step performed each day prior to going onsite is to log into the online tool to determine where you will be going and at what time you need to be there. Be sure to print out extra copies of onsite calculation forms. Ensure that you have printed several extra copies of the blank form in case there are issues with the prepopulated forms. You should also carry extra copies of the CPUC introduction letter in case clients are suspicious or unsure why you are conducting this study. They should have received a copy in the mail.

Step 2: Run Through the Equipment Checklist
Next, run through the equipment checklist to ensure that you have all of the tools necessary to complete the onsite work. Some of the more critical items include:

- Ladder
- Magnetic compass/smartphone
- Tape measure
- Digital camera
- Paper towel and window cleaner
- Inclinometer/smartphone
- Temperature probe
- General Tools Digital Solar Power Meter – DBTU1300
- Solmetric SunEye™
- Mirror-on-a-stick
- Flashlight

B.3 SAFETY PROTOCOL

The safety of the field crew, applicant, and host is the first priority. The inspector will not mount any roof, house, building, or structure under the following conditions:

- The inspector does not deem it to be safe. This could be if the roof is too steep, too slippery, too fragile, too wet, too hot, etc.
- The inspector judges that part of the roof could easily be damaged during the inspection.
- The inspector does not have a safe way to get up (i.e., ladder is damaged).
- The weather makes the conditions unsafe, such as lightning, strong wind, rain, etc.

If the inspector is unable to complete the inspection safely, s/he will work with the applicant and/or host to determine as best possible the most appropriate values for the inspection report.

Ladder Safety Checklist:

- Always have one person securing ladder while the other is climbing
- Always have a cell phone
- Use the ¼ ratio: 1 horizontal foot for every 4 vertical feet
- Extend ladder 3’ past roofline

General Field Safety Checklist:

- Work gloves
- Long sleeves
- Close-toed shoes with good traction
- Sunscreen
- Water

B.4 ONSITE PROCEDURE

Step 1: Introduction

Upon arriving at the site, the field crew should introduce themselves to the customer and request a few minutes to ask him/her general questions about the site and the location of the PV system components. Begin by briefly reiterating the purpose of the study, and have a copy of the CPUC introduction on hand. It is important to communicate clearly that the study is an energy study for which they will be compensated, and the field team has no relationship to the company that actually installed the system. Then ask the customer about the electric and gas utilities for the residence, and confirm this data in the field form. **If the electric utility is something other than PG&E, SCE, or SDG&E, thank the participant and terminate the site visit.**

Once the crew has had the chance to view the PV equipment and has made note of how best to access it, the host should be informed of the estimated time the inspection will take. The $50 gift card will be given to the host at this point.

Step 2: Data Collection and Verification

Once oriented on site, the field crew should work through the field form, collecting data in the most efficient way possible. The following sections map directly to the sections of the field form and are laid out in the manner in which they appear on the form. The Fulcrum data entry app is also laid out in such a way as to mimic the paper form.

Site Characteristics

1. Draw a quick sketch of the plan view layout of the site and location of the PV system(s). Include numerals corresponding to where on the site each photograph was taken. Take a photo of the sketch using the proper field in Fulcrum.
2. Photograph Check List – upload using the Fulcrum app.
    a. To differentiate one site from the next and to prevent confusion, take a photograph of the mailbox/house number. If either of these are not available/accessible, take a photo of the cover sheet for that site with the site address readable.
    b. Take a photo of the inverter/fuse boxes.
    c. Take a photo of the site sketch you drew (Step 1).
    d. Array photos will be taken from the Fulcrum app when collecting data about each array.

If the field crew identifies other interesting items that would benefit from a photograph (damaged/vandalized equipment, unconventional installation, etc.) please take extra photographs. These can be added to the inverter/Fuse Boxes photo or the array photos (Fulcrum allows more than one photo for each photo field).

3. Prepaid gift card – Record the last four numbers of the gift card given to owner, and have the customer sign the Fulcrum signature field.

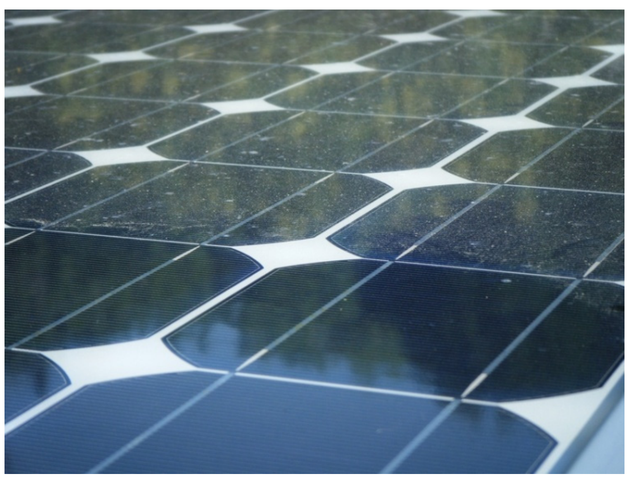
Soiling/System Condition

Soiling, in the form of accumulated dust or debris on the PV panels, can degrade the PV system's performance. Flat and near flat (<20°) panels are more susceptible to soiling.

1. For just one array, do a swipe test for a module with a clean rag, damp with window cleaning solution, to help quantify the degree of soiling.

2. Take a photograph of the swipe test area at a 45-degree angle from about 3 feet away, so that both the soiled and cleaned portions of the module are in the viewfinder. Try to avoid direct glare from the sun off the module. See Figure B-1 as an example.

Figure B-1. Typical Soiling Photograph



Source: Navigant Consulting, Inc.

3. Uploaded the file to the online database. Check this box once uploading is complete. Use the appropriate naming convention <SiteID>_<Array ID>_SoilingPhoto.jpg.

4. For each array, rate the degree of soiling from 0 (clean) to 5 (very dirty).

5. Note any damage to the system components including weather damage, and any evidence of tampering/vandalism or theft.

6. Make note of any obvious safety hazards such as frayed wires, loose mounting brackets, etc.

7. Note any other possible contributing factors to loss (or gain) of production.

Photovoltaic Modules

E1/E2. Manufacturer/Model Verification. Verify manufacturer and model numbers from the PV module nameplates. This will often require the use of a mirror-on-a-stick and a flashlight to see the nameplate on the back of panels. If the nameplates are inaccessible, see if the homeowner has invoices from the installer. If the panels are only a few inches off the roof, a 3’x4’ sheet of closed-cell foam may make it more comfortable to lie on the roof to get this information, as it will likely be hot to the touch on a sunny day. Also, in some instances, a camera can be used to take a picture if the nameplate is hard to reach.

E3/E4/E5. Count the number of modules installed for each Array ID. If possible, determine and record the number of modules per string, and number of strings in parallel for each array. This can usually be determined by inspecting the grouping of wires as they come into the fuse box or the inverter.

If there is no DC fuse box or you cannot access it, you can make an educated guess as to the number of panels in a string using the Optimal Voltage method. From the nameplate on the back of the PV panel, make a note of the panel’s typical operating voltage (not the open circuit voltage). This is the expected output voltage from the panel if the radiation it is receiving is 1,000 W/m^2. The following equation should give a rough estimate of the number of panels in series:

No. of Panels in Series ≅ Array DC Voltage / Panel Operating Voltage * Solar Radiation / 1000

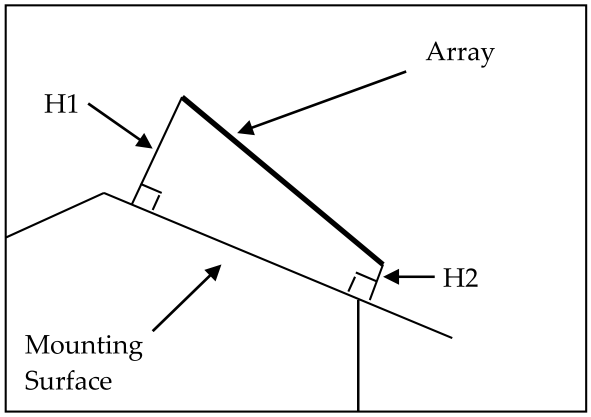
- Array DC Voltage can typically be read off the inverter display panel
- Operating Voltage (sometimes called Optimal Voltage) can be read off the nameplate
- Solar Radiation is the instantaneous insolation (in W/m^2) the array is receiving (see F3)

E6. Array Adjustment. Verify that the array is fixed, not a tracking system. All SASH sites should be fixed array types, but be sure to make a note if you find otherwise.

E7. Standoff Height. Using a tape measure or ruler, measure the standoff height from the mounting surface as the distance from the back of the PV module to the mounting surface.

For modules that are not parallel to the plane of the roof, use the average of the two following measurements: the maximum (H1) and minimum (H2) standoff distance of the array, as in Figure B-2

Figure B-2. Measurement of PV Standoff



The selections for standoff height are as follows:

- *0" average standoff (flush mount or BIPV)* – The PV modules are in direct contact with the mounting surface
- *>0" to 1" average standoff* – Average standoff is less than or equal to 1"
- *>1" to 3" average standoff* – Average standoff is less than or equal to 3" and greater than 1"
- *>3" to 6" average standoff* – Average standoff is less than or equal to 6" and greater than 3"
- *>6" average standoff* – Average standoff is greater than 6"

E8. Tilt from Horizontal. Using an inclinometer or digital level, measure the tilt of the PV modules parallel to the sloped edge of the panel. This will be prepopulated and our goal is to verify or dispute the number recorded. It is recommended that the reading be taken no less than three separate times, in order to be certain of the verification/dispute of the tilt. Particularly if your results differ significantly from the prepopulated values, it would be good to use more than one instrument (an inclinometer and a smart phone, for instance).

- For modules that are tilted along two axes, the measuring tool should be placed on a module and slowly rotated in the plane parallel to the module. The steepest angle seen during the rotation of the measuring tool is the tilt angle of the module.
- If the array is inaccessible, estimate the rise and run of the array on site and confirm with documentation from the installer, if available.
- Use the tilt of the array, not the roof shingles.
- Some smart phones have applications that can display the tilt of the surface. If you use one of these devices, be sure to calibrate it to a known level surface (you can use a carpenter's spirit level to verify the calibration surface is level).

E9. True Azimuth. The azimuth of an array is the horizontal direction that a module face is pointing. For arrays that are tilted along two axes, the azimuth is the horizontal direction of the steepest tilt. See Appendix 7 for a guide to taking a bearing on the azimuth. Again, this is a verification exercise. No less than three separate measurements should be taken until you are confident that the number is either verified or there is a discrepancy with the prepopulated values.

- The azimuth of an array pointing due south is 180 degrees.
- Take magnetic azimuth readings using a handheld compass 10-15 feet away from metal and unknown objects. Sometimes PV panels can cause error in a very sensitive compass (some digital compasses, for instance). It is good to verify the azimuth on the ground as well as on the roof.
- If using a regular needle compass, correct the magnetic azimuth reading to the true azimuth by adding the magnetic declination to the compass reading. The magnetic declination in California is typically 13 degrees to 16 degrees east of true north depending on the location of the site. Magnetic declinations can be obtained from www.ngdc.noaa.gov/geomagmodels/Declination.jsp.
- Azimuth is irrelevant when the tilt angle is 0 degrees.
- A simple way to verify azimuth angle on compound-angle systems is to spray water on the top of a panel until it runs downhill. As long as the wind is not blowing heavily, the direction of the drip is the direction of the azimuth.

E10. Identify the module STC (Standard Test Conditions) output (this is the DC rating) of the module, (i.e., 120W)

E11. Calculate the total array DC rating in Watts as E5*E10.

E12. Permanently Anchored. Verify that the array is permanently anchored.

Inverters

E13/E14. Manufacturer/Model Verification. Verify manufacturer and model from nameplate. You may need to use a screwdriver to carefully open the front panel of the inverter. If the nameplate is inaccessible, use invoices from the installer. If the inverter make and model does not match the prepopulated values on the data sheet, make a note.

E15.Number of Inverters. Verify the number of inverters. For micro-inverter systems (each panel has its own inverter), verify that the number of inverters is equal to the number of modules.

E16. Inverter Efficiency. The nameplate may or may not have the inverter’s efficiency listed. If it does, verify it with the prepopulated value from the data sheet.

E17. Verify the rated output for the inverter (usually included on the nameplate).

E18. Note the total AC production to date using the menus on the inverter display, if available. For multiple inverters, simply sum their total production values. Note that some inverters can be networked to indicate the combined system output on all displays.

E20. For each array, the data from the SunEye™ is needed for more in-depth analysis, and needs to be uploaded via the FACT system. The reports, data files, and shading snapshot images will be compressed as a zip file. The reports in this file are generated using averages of all skylines for each session stored in the SunEye™'s internal memory. To this end, any erroneous skylines should be deleted, and only one skyline should remain for each vertex of an array. Once the file has been uploaded to the FACT system, please check this box to confirm. The file should be named using the following convention: "<SiteID>_<ArrayID>_ShadingData.zip"

Shading

1. Use a Solmetric SunEye™ to perform the shading analysis. A separate shading analysis should be done for each unique array as determined earlier in this guide. The monthly shading derate factors should be entered into the field form. The SunEye™ will generate the needed averages, which can be recorded on the field sheet either in the field or once back at the office.
2. There are a number of ways to perform a shading analysis. The following are suggestions:
    a. The most common method is to take shading measurements at the major corners of an array and average the values for each month. "L" shaped arrays may require measurements at six points (one at each vertex).
    b. In cases where corner shade measurements do not adequately represent the shading of an array, it is critical that the positions of the shade measurements are documented and communicated so the analysis may be duplicated.

Spot Measurement

F1. Record the sky conditions (clear, partly cloudy, overcast).

F2. Record the time the measurement was taken.

F3. For each array, record the instantaneous solar radiation using the handheld solar radiation measuring tool. Make sure the units being displayed are W/m^2, not Btu/ft^2 (this can be done by pressing the SET button on the DBTU1300). The white spot on the top of the device is the solar radiation sensor. This should be aligned parallel to the array, such that the spot is receiving exactly the same sun and incidence angle as the array. This must be done simultaneously with F7, thus a team of two people is needed: one at the array, and one at the inverter.

F4. Record the temperature at the back of one of the panels in °C using the leaf-type thermocouple attached to the digital thermometer.

F5. Note whether the array is receiving shading from trees, chimneys, etc. at the time of the spot measurement. If so, this may mean the spot measurement will not be as indicative of the array's true performance with respect to the worst-case expected output.

F6. If you answered yes in F5, estimate the percentage of the array that is currently shaded.

F7. For each array, record the instantaneous power production in W by reading it off the inverter display. Inverters should have a display, which shows the instantaneous AC production of the connected array. *Simultaneous measurements should be coordinated among the field crew so as to occur at the same time. This will reduce variation in the solar radiation (due to clouds moving in front of the sun).*

F8. The power temperature coefficient for this array should be prepopulated (based on the PV manufacturer and model number listed in E1-E2). If not, or if there was a discrepancy with the observed equipment and the prepopulated equipment, use -0.004 as the power temperature coefficient.

F9. Using a calculator, determine the temperature-based derate factor using the equation listed on the field form.

F10. Using a calculator, determine the expected array output from the equation given on the field form.

F11. Compare the expected (theoretical) output from F10 with the instantaneous (observed) output. Circle Y if the actual output is less than the expected output, otherwise circle N.

If you marked Y for F11, and the array is not receiving shading, there may be some problems with wiring, or damage to the system causing one or more of the panels (or strings) to perform poorly. In order to determine whether there is any mismatch in production between strings, the troubleshooting section (F12) should be completed, and try to figure out what could be causing the mismatch. You should then call the field coordinator, whose cell number appears on the field form for that purpose.

F12. Note whether there are two arrays with differing tilt or azimuth values

F13. If you marked Y for F12, try to determine whether both arrays are connected to one inverter. If this is the case, the spot measurements will be less relevant and a failed spot test should not be cause for concern in this instance.

Sites Requiring Multiple Forms

Page 2 of the field forms is required for every unique Array ID. An Array ID is required per array if any of the following is encountered on site.

- PV modules with different STC rated outputs are installed at one location. A separate Array ID must be created and a field form must be filled in for each type of module so that the different arrays can be modeled individually.
- An installation is split into sections having different tilt angles or different azimuth orientations. A unique Array ID must be used for each section of the array.
- Inverter models with different peak efficiencies are installed at one location. Unique Array IDs must be used for each type of inverter (making sure the PV panels associated with each are included in the sheet).

- If there is more than one array for a site, each array must have a separate Array ID. (1, 2, 3, etc.)

B.5 UPON RETURNING FROM THE FIELD

Download data from the Solmetric SunEye™

1. For each array, save the generated zip file from each session with the following filename format: <SiteID>_<arrayID>_ShadingData.zip For example, for a site with an ID of 0621, and an array with ID of 2, the filename should be "0621_2_ShadingData.zip"
2. Make sure the shading file is close at hand, as it will need to be e-mailed to the field coordinator

B.6 FIELD DATA COLLECTION INSTRUMENT

Because Navigant transitioned to using tablets for data collection, there is no paper form showing each data point collected in the field. In lieu of a paper form, the following is a list of the fields collected in the tablet field form. The list below does not capture the true data validation and flow logic of the data collection app and is included for illustration.

1. Customer Information/Scheduling [Prepopulated]
    1. Site ID
    2. Contact name
    3. Address
    4. Other Units
    5. Business
    6. E-mail
    7. Phone Number
    8. Alt. Phone Number
    9. Utility Name
    10. Scheduler
    11. Scheduled Date
    12. Scheduled Time
    13. Site Type [SASH / MASH]
    14. Number of Stories
    15. Notes
2. Site Characteristics [One per Site]
    1. Dwelling Type [Mobile Home / Single Family / Attached < 4 Units / Attached > 4 Units]
    2. House/Mailbox Number Photo
    3. Building Number/Entrance Photo
    4. Inverter/Fuse Boxes Photo
    5. Site Sketch Photo
    6. Customer Signature
    7. Gift Card Number
    8. Notes
    9. System Condition (for one array typical to the site)
        1. Performed Swipe Test? [yes / no]

2. Swipe Test Photo
3. Level of Soil on Surface (0 is perfectly clean & 5 is very dirty) [0 / 1 / 2 / 3 / 4 / 5]
4. Safety Issues Found? [yes / no]
5. Damage Found [None / Normal Wear / Weather / Other (specify)]
6. Notes

3. Photovoltaic System Verification

Array and Inverter Characteristics [Fill out one per array]

1. Array Title
2. Array ID
3. PV Manufacturer [Prepopulated]
4. Is the Manufacturer Name Correct?
5. Actual Manufacturer Name
6. PV Model Number [Prepopulated]
7. Is the Model Number Correct?
8. Actual Model Number
9. Number of Panels [Prepopulated]
10. Is the Number of Panels Correct?
11. Actual Number of Panels [Prepopulated]
12. Array Adjustment [Prepopulated as "fixed" for all SASH and MASH arrays]
13. Is the Array Adjustment Correct?
14. Actual Array Adjustment
15. Standoff Height
16. Tilt from Horizontal [Prepopulated for MASH]
17. Is Tilt from Horizontal Correct within 3 degrees?
18. Actual Tilt from Horizontal
19. True Azimuth (180 = South) [Prepopulated for MASH]
20. Is the True Azimuth Correct within 5 degrees?
21. Actual True Azimuth (180 = South)
22. Notes
23. Measure Shading: Take one "Skyline" at each corner of the array, zip all with Site ID and Array ID in the filename and send to field coordinator
24. Inverter Characteristics
    1. Manufacturer [Prepopulated]
    2. Is the Manufacturer Name Correct?
    3. Correct Manufacturer Name
    4. Model Number [Prepopulated]
    5. Is the Model Number Correct?
    6. Correct Model Number
    7. Number of Inverters [Prepopulated]
    8. Is the number of inverters correct?
    9. Correct Number of Inverters [Prepopulated]
    10. Inverter Efficiency [Prepopulated]
    11. Is the Inverter Efficiency Correct?
    12. Correct Inverter Efficiency
    13. Rated Output

14. Production to Date (if available. Use -1 to indicate "Inverter does not have a display")
15. Notes

Spot Measurement and Onsite Calculations

1. Sky Cover
2. Time
3. Is the Array Currently Receiving Shading?
4. Estimated % of Array Shaded
5. Is the Actual Output less than the Expected Output (by more than 10%)?
6. If so, call field coordinator
    1. Are there Multiple Arrays with Differing Tilt or Azimuth?
    2. Are the Arrays Connected to the Same Inverter
7. Upload Photo of Onsite Calculation
8. Notes

Appendix C Detailed Methodology and Assumptions

C.1 BILL IMPACTS

Table C-1 to Table C-5 outline some of the specifics of the billing analysis. Note that the rate classes chosen are intended to cover the majority of accounts present in the billing data we received from the PAs. SDG&E commercial rates had very low representation in the data in the data so the billing impacts analysis includes only the two residential rates in the model for SDG&E. This means the SDG&E MASH owner bill savings are based on a blend of the highest tiers of the demand response (DR) and DRLI residential rates. While this does not reflect true conditions, it provides a rough approximation of the owner bill impacts for SDG&E.

Table C-1. MASH Simplified Rate Class Proportions

IOU	Rate Class	Weight by IOU	Residential	Res-only Weight
SDG&E	DR	0.470	Y	47%
	DRLI	0.530	Y	53%
SCE	Domestic	0.328	Y	42%
	D-CARE	0.460	Y	58%
	TOU-GS1A	0.126	N	-
	GS1	0.087	N	-
PG&E	A6	0.062	N	-
	E1	0.854	Y	91%
	EL1	0.085	Y	9%

Source: PA-provided monthly billing data

Table C-2. SASH Simplified Rate Class Proportions

IOU	Rate Class	Weight by IOU	CARE vs. Non-CARE
SDG&E	DR	31%	Non-CARE
SDG&E	DRLI	69%	CARE
SCE	Domestic	18%	Non-CARE
SCE	D-CARE	82%	CARE
PG&E	E1	22%	Non-CARE
PG&E	EL1	78%	CARE

Source: PA-provided monthly billing data

Table C-3. Estimated CARE Participation Percentage 2011-2013

	PG&E	SCE	SDG&E
MASH	9%	58%	53%
SASH	78%	82%	69%

Source: Navigant analysis of PA-provided monthly billing data

Table C-4. MASH Tenant Estimated CARE and Non-CARE Enrollment Used in Bill Impacts

IOU	Install Year	CARE	Non-CARE
PG&E	2011	78.0	844.0
	2012	62.3	673.6
	2013	30.0	325.0
SCE	2011	94.5	111.5
	2012	218.0	257.0
	2013	291.9	344.1
SD	2011	377.5	334.5
	2012	168.1	148.9
	2013	83.2	73.8

Note: Estimates are based on proportions of CARE versus Non-CARE present in billing data applied to database quantities by IOU and year so numbers are not integers.
Source: Navigant analysis of PA-provided billing data and PowerClerk database

Table C-5. SASH Tenant Estimated CARE and Non-CARE Enrollment Used in Bill Impacts

IOU	Install Year	CARE	Non-CARE
PG&E	2011	328.8	93.2
	2012	530.5	150.5
	2013	302.3	85.7
SCE	2011	244.6	52.4
	2012	420.0	90.0
	2013	385.5	82.5
SD	2011	65.2	28.8
	2012	91.5	40.5
	2013	119.2	52.8

Note: Estimates are based on proportions of CARE versus Non-CARE present in billing data applied to database quantities by IOU and year so numbers are not integers.
Source: Navigant analysis of PA-provided billing data and Salesforce database

C.2 WEATHER

Navigant downloaded actual hourly weather data from the California Irrigation Management Information System (CIMIS) for 2011, 2012 and 2013. The network has 120+ stations spread geographically across California in order to provide relevant meteorological data for making decisions about irrigation practices throughout the state. The data available at CIMIS weather stations contains most of the required inputs to the hourly solar PV model. Although the weather stations collect a wide range of data, the following list shows the data that are relevant to the modeling effort:

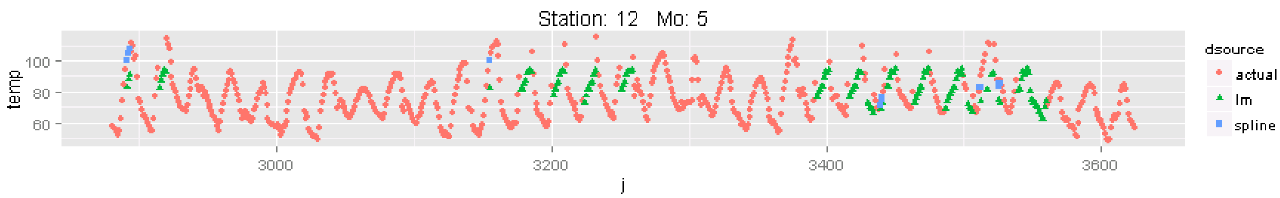
- Total Horizontal Solar Radiation
- Dry Bulb Temperature
- Dew Point Temperature
- Relative Humidity
- Wind speed

After downloading hourly data for all active CIMIS weather stations, the analysis team cleaned the data with the following approach:

1. Navigant set values outside reasonable ranges expected for the California climates to missing.
   a. Solar radiation values greater than 1350 W/m^2 and less than zero were discarded
   b. Temperatures below -50 and above 150 degrees F were discarded.
   c. RH values outside the range 0-100 percent were discarded.
2. Navigant confirmed regular data intervals between observations.
   a. If more than one observation occurred in one hour, the values were averaged for that hour.
   b. If observations were more than an hour apart, data was interpolated according to step 3 below in order to create 8,760 continuous values.
3. Navigant interpolated/filled missing data for gaps less than 15 days and removed sites with 15 days or more of missing values (missing data represents about 0.5 percent of the data points for sites without data gaps of 15 days of longer).
   a. Data gaps of three hours or less with three hours of good data both before and after were interpolated using the spline interpolation method.
   b. Data gaps of longer than three hours and less than 15 days were filled using monthly regression models. Navigant fit the models such that each hour of the day receives its unique slope and intercept over the month. This approach captures annual trends, like falling temperatures during October, and also maintains a consistent daily pattern over the month.
   c. Stations with data gaps of 15 days or longer were thrown out.

Figure C-1 exemplifies this approach, where the y-axis is temperature in Fahrenheit (temperature) and the x-axis is Julian hours (j). This graph is limited to May 2014 at station 12 and measured data appears as red diamonds, spline-interpolated data points appear as blue squares and regression-model-interpolated data points appear as green triangles. Navigant chose to present data from May 2014 because it best demonstrates both liner and spline interpolation methods.

Figure C-1. Actual and Interpolated Outdoor Temperature for May 2014 at Station 12



Source: Navigant Consulting, Inc.

Navigant did not adjust any measured data points in the CIMIS data other than solar radiation. Most PV solar models, including the model used for this study, require that the beam and diffuse components of solar radiation be separate inputs. Because the instrument necessary to collect beam solar radiation data separately (called a pyrheliometer) is much more expensive and difficult to maintain than a normal pyranometer, standard methods for decoupling the beam and diffuse components of the solar radiation exist. For this study, the analysis team used the Boland-Ridley model, which, like many models, uses the clearness index to predict the diffuse component.[145]

Once the analysis team cleaned the weather data, they matched each SASH site with the closest CIMIS weather station, using a database of latitude and longitude associated with U.S. ZIP codes. The formula used to calculate distance between two points is called the great circle formula. The distance of a site from the nearest weather station is important because solar radiation varies geographically, especially on partly cloudy days. This primarily affects the peak demand impacts results, as the output of the system is required on a particular hour of a particular day. Estimating the uncertainty associated with this approach would be an involved and time-consuming process, beyond the budget and scope of this study. Therefore, energy, demand, greenhouse gas, and billing impacts are reported without estimated uncertainty.

For CIMIS stations, Navigant matched 483 unique ZIP codes across California from SASH and MASH projects with the closest stations, with a total of 71 CIMIS stations used. The maximum distance between a TMY location and site ZIP code's centroid is 120 miles, with 90 percent of stations under 30 miles distant.

Additionally, Navigant matched projects with nearest TMY data as well to get typical year results. Navigant matched 483 unique ZIP codes with the closest TMY stations, with a total of 105 TMY locations used. The maximum distance between a TMY location and site ZIP code's centroid is 28 miles.

[145] http://solar.org.au/papers/08papers/252.pdf

C.3 PV CHARACTERISTICS PDF SCRAPING

Navigant used text mining techniques to extract equipment and installation characteristics out of EPBB files for SASH or third-party inspection forms (for MASH). Effectiveness of this scraping process (as measured by percentage of successfully scraped sites) was limited due to ubiquity of scanned documents and varying file formats. PDF scraping effectiveness is discussed in more detail Appendix A and is as follows:

1. Ignore all scanned files or images (including PDFs containing only scanned images)
2. Use xpdf, a command-line tool to convert all remaining PDF files to plain text[146]
3. Batch read all text files into R as raw character data
4. Parse text using regular-expression searches based on differing file formats and (for MASH) multiple arrays per file —this step involved much trial-and-error and incremental coding
5. Parse EPBBs saved as HTML (fairly straightforward)

The end result from this process was a dataset containing approximately 30 variables scraped from the EPBB or FIWS, with one row per array at each SASH and MASH site. The next step involved fuzzy-merging the scraped data with the PowerClerk and Salesforce data.

SASH Matching
There is no key tying EPBB printouts to specific SASH projects, but the printouts generally contain customer name and/or address information. Navigant developed special key strings containing identifying information about each array/site, even though there were differences in spelling or initials between EPBB printouts and the program databases. Navigant then used string difference metrics from the *stringdist* package in R to find closest matches. Match effectiveness was verified by manual checking, and the error rate was determined to be less than 5 percent.

SASH key strings contained the GRID assigned office concatenated with street address and customer name. The house number was followed by an 8-character MD5 hash of random characters based on that house number to give more weight. Typical SASH matching strings might look like this (differences underlined):
From EPBB: "`Central Coast/1102 69965d1c Main Street - Smith, J.`"
From Salesforce: "`Central Coast/1102 69965d1c Main St. - Smith, John`"

MASH Matching
For MASH, the inspection worksheet contained application ID, but did not follow the same numbering convention for arrays as Salesforce. Within each application, Navigant had to match arrays correctly based only on array characteristics. Navigant developed a matching string from both inspection worksheet data and PowerClerk data containing the following information:

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[146] After testing many open-source and paid PDF conversion methods, xpdf yielded the text files most suitable for text mining: http://www.foolabs.com/xpdf/

- Module Quantity
- Tilt
- Azimuth
- PV Module Model number
- 5-character MD5 hash of module quantity (to lend more weight to quantity in the string distance metric)

C.4 SAM MODEL ASSUMPTIONS

SAM

SAM has an advanced equipment-based modeling capability, which draws on an up-to-date database of empirically determined PV and inverter characteristics in order to more accurately simulate PV system performance. SAM also has a scripting interface called SAMul (System Advisor Model User Language) which allowed the analysis team to set up batch model runs, facilitating a more coordinated modeling approach. Navigant used the 2014.1.30 version of SAM for the simulation. The results generated by the PV modeling are available in form of raw text files or comma separated value files. Navigant used the raw text files in other analysis tools like R for the purpose of verification.

Input List

In Table C-6, Navigant has provided the list of input that go in the 8,760 hourly PV production model in SAM.

Table C-6. Input List with Description and Source

Input Variable	Description	Source
arraySTC	DC Array rating (STC) to use for SAM system autodesign	EPBB
arrayPTC	DC Array rating (PTC) provide solely for roll-up purposes later on	EPBB
pvMfgModel	Name of the PV Manufacturer/Module as it lines up with the SAM CEC database	EPBB
inverterMfgModel	Name of inverter manufacturer/model as it lines up with the SAM CEC database	EPBB
Tilt	Angle of panel above horizontal	EPBB
Azimuth	Orientation Angle (180 = south)	EPBB
minShading	If 1, all shading objects are >2H away from array (no shading derate required) if 0, use monthly shading values (representing fraction of solar availability)	EPBB
mountingMethod	0 = Building Integrated 1 = Greater than 3.5" 2 = 2.5-3.5" 3 = 1.5-2.5" 4 = 0.5-1.5" 5 = 0-0.5" 6 = ground/rack mounted	EPBB
weatherstring	Station ID for constructing weather filename to match the CIMIS weather filename	CIMIS
tmystring	TMY filename for closest TMY location to the site	NREL

Source: Navigant Consulting, Inc.

SAM System Autodesign

SAM provides two options for the performance modeling. The first option involves giving an input of the desired array size in kW-DC (STC) and the expected DC to AC ratio. The DC to AC ratio is the ratio of the nameplate capacity or the desired array size to the total inverter capacity. Ideally, this ratio is always one, which means there is no mismatch between the PV panels and the inverter capacity. SAM auto calculates this ratio based on the PV panel and inverter selection. SAM uses the actual ratio for the purpose of simulation. The second option is entering the number of PV modules, inverters and number of strings in parallel per inverter. The number of modules and inverters are available from either the EPBBs or the program database for each site, but the number of strings in parallel is not available. Navigant ran the model with the default assumption of one, but this resulted in an unrealistic DC to AC ratio. Therefore, Navigant decided to opt for the first option in which SAM auto designs the system for the desired array size and the array STC value available from the EPBB's is used as an input.

Shading Derate

Navigant field verification team collected spot measurements of the shading coefficients for each month using the Solmetric SunEye handheld spot measurement device. The PAs also provided the monthly shading coefficients through their EPBB forms for the sites that Navigant did not visit. A general rule that applies across all the SASH and MASH sites, is that if the distance of the nearest obstacle is two times the height of the building on which the panels are installed, then the shading derate is minimal. In other words, the full solar fraction is utilized to generate electricity without any loss due to shading. SAM has four methods of handling the shading derate:

1. Hourly beam irradiance shading factors - The hourly 8,760 option is appropriate if you have a set of hourly beam shading factors for each of the 8,760 hours in a year.
2. Month by hour beam irradiance shading factors - The month by hour shading factor matrix is a 24-by-12 table containing a set of 24 hourly shading factors for each month of the year. The shading factor in a cell applies to a given hour for an entire month.
3. Solar azimuth by altitude beam irradiance shading factors - The solar azimuth by altitude table is a two-dimensional look-up table of beam irradiance shading factors. For each hour in the simulation, SAM calculates the position of the sun as a set of solar azimuth and altitude angles and looks up the shading factor to use for that hour based on the solar position. SAM uses linear interpolation to estimate the value of the shading factor for solar angles that fall between values in the table row and column headings.
4. Sky diffuse shading factor - A shading factor for sky diffuse radiation may be used. This factor is applied to every hour in the year. This value is considered to be the fraction of the sky that is obstructed, and is therefore constant.

Navigant applied the available values for every month to each hour of the month as that was the only form of data available from PAs and field verification. SAM uses the values only from sunrise to sunset and factors the beam solar radiation from the weather data to account for the shading derate.

C.5 SAM MODEL CALIBRATION

Navigant developed two sets of calibration factors for both SASH and MASH. The calibration factors are specific to coastal versus inland climates, and represent the number of watt-hours to add to modeled output to get a calibrated result.

Navigant calculated the calibration factors in the tables below by first averaging VNM energy production by inland versus coastal and by month and hour, creating a 12x24 array of kWh. Then, Navigant calculated averaged modeled production at those same sites over the same time frames and climate zones. The correction factor tables are simply the hour-by-hour difference between the modeled and metered VNM data.

The only difference between the SASH and MASH tables is the inclusion of two sites where VNM data differed drastically from modeled data. Navigant had no reason to believe the difference was due to modeling error, meaning the difference was most likely specific only to MASH, Thus the SASH calibration factors do not include those outliers in the calculations while the MASH factors do.

Table C-7. MASH Coastal VNM Correction Factors (Watt-hours added to modeled output)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.13	0.13	0.13
2	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.13	0.13	0.13
3	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.15	0.14	0.14	0.13	0.13
4	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.13	0.13
5	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
6	0.13	0.13	0.14	0.21	0.78	1.01	0.42	0.17	0.14	0.13	0.13	0.13
7	0.28	1.44	1.52	3.83	3.01	-2.15	2.73	3.29	1.24	0.31	2.59	0.40
8	9.63	12.23	5.42	0.45	-7.15	-12.14	4.74	9.74	7.25	6.12	11.10	10.58
9	20.39	56.55	14.71	2.70	0.60	0.80	12.99	16.01	7.80	21.62	29.42	10.21
10	52.37	91.55	48.81	59.21	72.80	44.01	43.62	36.12	55.94	45.97	62.53	45.88
11	102.73	156.70	104.63	104.63	114.82	79.12	91.84	75.38	105.83	81.37	101.59	86.40
12	130.81	161.95	140.65	135.65	134.69	115.84	128.19	123.77	137.16	109.27	120.90	110.16
13	127.75	164.40	126.59	131.99	152.35	142.38	139.57	160.41	171.88	119.02	114.80	113.28
14	116.85	162.42	141.32	118.38	150.33	166.77	142.29	144.36	169.53	112.69	105.43	83.64
15	91.95	129.05	132.05	100.61	132.53	139.00	122.49	130.19	143.50	100.59	61.52	56.24
16	63.97	77.63	93.86	97.85	102.56	118.57	88.10	103.72	124.33	68.10	42.60	53.32
17	43.68	38.50	61.81	67.05	68.39	79.79	35.43	52.97	64.67	32.20	24.45	25.34
18	2.72	20.67	27.79	15.16	16.44	24.61	-7.00	6.88	13.98	33.62	2.22	0.13
19	0.13	0.13	15.92	2.16	-23.42	-22.73	-40.03	-18.71	20.16	5.84	0.14	0.13
20	0.13	0.13	0.86	6.81	-1.17	-10.63	-10.79	4.88	0.96	0.13	0.13	0.13
21	0.13	0.13	0.12	0.12	0.28	1.46	0.93	0.16	0.14	0.13	0.13	0.13
22	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.14	0.14	0.14	0.14	0.13
23	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.13	0.13	0.13	0.13
24	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.13	0.13	0.13

Source: Navigant Consulting, Inc.

Table C-8. MASH Inland VNM Correction Factors (Watt-hours added to modeled output)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.21	0.21	0.21	0.18	0.19	0.19	0.18	0.18	0.18	0.19	0.19	0.19
2	0.21	0.21	0.21	0.18	0.19	0.18	0.18	0.18	0.18	0.19	0.19	0.19
3	0.21	0.21	0.21	0.18	0.19	0.19	0.19	0.18	0.18	0.19	0.19	0.19
4	0.21	0.21	0.21	0.18	0.19	0.19	0.18	0.18	0.18	0.19	0.19	0.19
5	0.21	0.21	0.21	0.18	0.19	0.20	0.19	0.18	0.18	0.19	0.19	0.19
6	0.21	0.21	0.21	0.18	0.51	1.09	0.25	0.18	0.18	0.19	0.19	0.19
7	0.21	0.60	1.19	3.98	7.04	3.19	4.47	5.75	1.63	0.27	3.23	0.33
8	11.19	20.56	14.57	10.32	21.85	12.59	12.95	7.14	10.34	11.63	22.14	16.02
9	50.77	70.69	51.71	58.58	70.35	68.25	58.64	39.29	47.91	39.28	70.45	56.26
10	113.61	134.56	106.78	117.22	124.65	123.95	113.57	97.35	91.29	88.90	96.60	103.15
11	150.23	164.63	157.72	172.67	169.86	157.12	162.51	154.33	136.88	120.66	113.60	130.72
12	171.65	177.89	192.25	196.59	170.46	172.84	175.73	163.60	146.43	142.85	117.07	137.15
13	177.18	177.20	185.89	188.94	170.00	173.36	169.77	155.45	145.29	134.30	107.91	130.52
14	155.42	160.79	168.80	170.70	154.25	164.33	157.96	129.71	123.41	119.47	85.96	99.86
15	110.00	133.28	142.63	138.95	138.82	145.72	133.60	105.78	106.98	97.67	47.94	56.02
16	50.36	84.73	122.34	118.40	119.18	123.32	107.42	83.52	77.26	64.64	15.48	21.44
17	20.97	27.98	73.79	86.32	97.53	87.79	85.19	69.46	45.41	20.43	9.83	14.29
18	1.28	10.47	26.14	37.86	48.11	46.92	42.25	19.84	14.19	9.58	0.64	0.19
19	0.21	0.21	8.15	0.73	2.76	-1.21	3.48	-8.45	4.96	3.75	0.19	0.19
20	0.21	0.21	0.95	6.83	6.78	-0.43	2.10	4.84	1.01	0.19	0.19	0.19
21	0.21	0.21	0.21	0.18	0.46	2.49	2.02	0.22	0.18	0.19	0.19	0.19
22	0.21	0.21	0.21	0.18	0.19	0.19	0.20	0.18	0.18	0.19	0.19	0.19
23	0.21	0.21	0.21	0.18	0.19	0.18	0.19	0.18	0.18	0.19	0.19	0.19
24	0.21	0.21	0.21	0.18	0.19	0.18	0.19	0.18	0.18	0.19	0.19	0.19

Source: Navigant Consulting, Inc.

Table C-9. SASH Coastal VNM Correction Factors (Watt-hours added to modeled output)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.13	0.13	0.13
2	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.13	0.13	0.13
3	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.15	0.14	0.14	0.13	0.13
4	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.13	0.13
5	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
6	0.13	0.13	0.14	0.21	0.78	1.01	0.42	0.17	0.14	0.13	0.13	0.13
7	0.28	1.44	1.52	3.83	3.01	-2.15	2.73	3.29	1.24	0.31	2.59	0.4
8	9.63	12.23	5.42	0.45	-7.15	-12.14	4.74	9.74	7.25	6.12	11.1	10.58
9	20.39	56.55	14.71	2.7	0.6	0.8	12.99	16.01	7.8	21.62	29.42	10.21
10	52.37	91.55	48.81	59.21	72.8	44.01	43.62	36.12	55.94	45.97	62.53	45.88
11	102.73	156.7	104.63	104.63	114.82	79.12	91.84	75.38	105.83	81.37	101.59	86.4
12	130.81	161.95	140.65	135.65	134.69	115.84	128.19	123.77	137.16	109.27	120.9	110.16
13	127.75	164.4	126.59	131.99	152.35	142.38	139.57	160.41	171.88	119.02	114.8	113.28
14	116.85	162.42	141.32	118.38	150.33	166.77	142.29	144.36	169.53	112.69	105.43	83.64
15	91.95	129.05	132.05	100.61	132.53	139	122.49	130.19	143.5	100.59	61.52	56.24
16	63.97	77.63	93.86	97.85	102.56	118.57	88.1	103.72	124.33	68.1	42.6	53.32
17	43.68	38.5	61.81	67.05	68.39	79.79	35.43	52.97	64.67	32.2	24.45	25.34
18	2.72	20.67	27.79	15.16	16.44	24.61	-7	6.88	13.98	33.62	2.22	0.13
19	0.13	0.13	15.92	2.16	-23.42	-22.73	-40.03	-18.71	20.16	5.84	0.14	0.13
20	0.13	0.13	0.86	6.81	-1.17	-10.63	-10.79	4.88	0.96	0.13	0.13	0.13
21	0.13	0.13	0.12	0.12	0.28	1.46	0.93	0.16	0.14	0.13	0.13	0.13
22	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.14	0.14	0.14	0.14	0.13
23	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.13	0.13	0.13	0.13
24	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.13	0.13	0.13

Source: Navigant Consulting, Inc.

C.6 DEFAULT ASSUMPTIONS FROM THE E3 CSI SINGLE-INSTALLATION COST-EFFECTIVENESS TOOL

The following PV system cost and financing assumptions, which Navigant used without modification, were default assumptions from the E3 Cost-Effectiveness Tool.

Table C-10. PV System Recurring Ownership Cost Parameters

Customer Type	Size (kW-DC [STC])	O&M Costs ($/kW-DC [STC])	O&M Cost Escalator (%/yr)	Inverter Replacement time (Years)	Insurance Expense (% of CAPEX)	Insurance Escalator (%/yr)
Residential	<10 kW	30	2.0%	10	0.4%	2.0%
	10-100 kW	30	2.0%	10	0.4%	2.0%
	100-500 kW	30	2.0%	10	0.4%	2.0%
	>=500 kW	30	2.0%	10	0.4%	2.0%
Commercial	<10 kW	25	2.0%	10	0.5%	2.0%
	10-100 kW	25	2.0%	10	0.5%	2.0%
	100-500 kW	25	2.0%	10	0.5%	2.0%
	>=500 kW	25	2.0%	10	0.5%	2.0%
Government	<10 kW	25	2.0%	10	0.5%	2.0%
	10-100 kW	25	2.0%	10	0.5%	2.0%
	100-500 kW	25	2.0%	10	0.5%	2.0%
	>=500 kW	25	2.0%	10	0.5%	2.0%
Non-Profit	<10 kW	25	2.0%	10	0.5%	2.0%
	10-100 kW	25	2.0%	10	0.5%	2.0%
	100-500 kW	25	2.0%	10	0.5%	2.0%
	>=500 kW	25	2.0%	10	0.5%	2.0%

Source: E3

Table C-11. PV System Financing Parameters

Parameter	Residential	Commercial	Government	Non-Profit	Non-Profit
Financing Choice	Private Ownership - Debt/Equity	Private Ownership - Debt/Equity	Private Ownership - Debt/Equity	Private Ownership - Debt/Equity	TPO - PPA/Lease
WACC	4.36%	8.25%	4.21%	8.25%	8.25%
Percent Financed with Equity	40%	60%	40%	40%	60%
Debt Interest Rate	5.50%	7.67%	4.21%	7.67%	7.67%
Cost of Equity	5.50%	10.72%	4.21%	9.12%	Optimized
Target Minimum DSCR	N/A	N/A	N/A	N/A	1.4
Years of Debt Service in DSRF	0	1	0	0	1
Debt Period in Years	20	20	20	20	20
Federal Tax Rate	28.00%	35.00%	0.00%	0.00%	35.00%
State Tax Rate	9.30%	8.84%	0.00%	0.00%	8.84%
Tax Credit Rate	30%	30%	0%	0%	30%
Tax Credit Expiration	2016	2016	0	0	2016
MACRS Term	5	5	0	0	5

Source: E3

Table C-12. Inverter Replacement Costs ($/W-DC)

Year of Replacement	<10 kW-DC (STC)	10-100 kW-DC (STC)	100-500 kW-DC (STC)	>=500 kW-DC (STC)
2022	0.36	0.31	0.25	0.25
2023	0.34	0.29	0.24	0.24
2024	0.32	0.28	0.23	0.23

Source: E3

C.7 DETAILED COST AND BENEFIT LIST

Table C-13 provides a list of common inputs used in various cost-effectiveness studies. The table states the source for the input if it was included in Navigant's analysis.

Table C-13. Detailed List of Cost-Benefit Inputs with Their Sources

Inputs	Source
Administrative costs	Provided by PA's and from CSI Semi-Annual Expense Report
Avoided costs of supplying electricity - generation capacity	E3 NEM Avoided Cost Model (4/7/2015 version)
Avoided costs of supplying electricity - energy	E3 NEM Avoided Cost Model (4/7/2015 version)
Avoided costs of supplying electricity - T&D	E3 NEM Avoided Cost Model (4/7/2015 version)
Avoided costs of supplying electricity - GHG	E3 NEM Avoided Cost Model (4/7/2015 version), where the EPA's societal cost of carbon was used in the SCT test
Avoided costs of supplying electricity - avoided RPS	E3 NEM Avoided Cost Model (4/7/2015 version)
Avoided costs of supplying electricity - avoided ancillary services	E3 NEM Avoided Cost Model (4/7/2015 version)
Bill Increases/Reduction	PV energy savings (from SAM) multiplied by rate schedules for different rate classes (from IOUs) and escalated by forecasted escalation rates (from IOUs)
Capital costs to utility	None
Incentives paid	PowerClerk and Salesforce databases
Increased supply costs	None included
Non-energy social benefits	EPA's societal cost of carbon used for SCT test
Non-energy utility benefits	Utility NEBs included from LIPPT model
Non-energy participant benefits	Participant NEBs included from LIPPT model
Participant Costs - Equipment/Installation (Measure Costs)	PowerClerk and Salesforce database
Revenue gain from increased sales/loss from reduced sales	Negative of bill impacts
Tax Credits	E3 Single-Installation Cost-Effectiveness Tool

Source: Navigant Consulting, Inc.

C.8 SASH COST-EFFECTIVENESS MODEL INPUTS

This section includes the SASH data Navigant used as input to its Analytica-based Cost-Effectiveness Calculator. Although Navigant used output from other tools and pre-processed much of the input data before entering the Calculator, this data's high level of granularity provides additional insight to interested parties. Additionally, stakeholders can use these inputs along with discount rates from Section 2.3.4.1, administrative costs from Section 2.3.3.4, a PV production degradation rate of 1.25 percent/year, and an inflation rate of two percent/year to re-create our cost test results.

Table C-14 provides the all of the components of the SASH cost tests except the avoided costs and the participant bill savings. These inputs are disaggregated by installation group, which is every IOU, installation year and climate zone combination.

Table C-14. SASH Cost-Effectiveness Inputs by Installation Group

Installation Group	NPV of System Ownership Cost (PCT) [1]	NPV of System Ownership Cost (TRC, PAC, RIM) [1]	NPV of System Ownership Cost (SCT) [1]	CSI Rebates	NPV of Participant NEBs [2]	NPV of Utility NEBs [3]	First-Year Energy Savings	Installed Capacity	Number of Projects
IOU | Install Year | Climate Zone	$	$	$	$	$	$	kWh/year	kW-DC (STC)	projects
PG&E | 2011 | 1	190,393	187,910	190,701	182,327	973	10,348	35,037	33.1	7
PG&E | 2011 | 11	435,121	429,500	435,817	416,879	1,807	19,218	103,007	75.0	13
PG&E | 2011 | 12	386,948	382,055	387,554	371,046	2,502	26,609	97,590	65.3	18
PG&E | 2011 | 13	1,813,812	1,790,246	1,816,731	1,737,422	11,814	125,655	460,721	314.5	85
PG&E | 2011 | 2	1,501,734	1,482,794	1,504,080	1,440,161	7,088	75,393	390,954	252.7	51
PG&E | 2011 | 3	2,097,081	2,068,524	2,100,619	2,004,682	17,651	187,743	543,251	381.1	127
PG&E | 2011 | 4	1,634,821	1,613,093	1,637,512	1,564,948	13,621	144,873	477,485	290.0	98
PG&E | 2011 | 5	327,524	323,191	328,061	313,495	3,197	34,001	91,230	57.8	23
PG&E | 2012 | 1	508,932	502,725	509,701	488,710	2,858	30,187	109,545	86.9	20
PG&E | 2012 | 11	3,169,994	3,127,657	3,175,237	3,032,096	21,577	227,914	907,651	592.7	151
PG&E | 2012 | 12	889,518	878,406	890,894	853,362	5,716	60,375	230,007	155.5	40
PG&E | 2012 | 13	3,017,272	2,979,759	3,021,918	2,895,326	16,576	175,086	801,422	525.0	116
PG&E | 2012 | 2	1,774,706	1,753,320	1,777,355	1,705,730	7,573	79,996	444,793	299.5	53
PG&E | 2012 | 3	2,592,926	2,559,814	2,597,027	2,485,553	22,863	241,498	675,321	463.6	160
PG&E | 2012 | 4	2,179,195	2,151,216	2,182,660	2,088,275	15,433	163,011	658,469	391.7	108
PG&E | 2012 | 5	473,006	466,622	473,796	452,293	4,716	49,809	140,041	89.4	33
PG&E | 2013 | 1	227,056	224,247	227,404	217,982	1,720	18,320	56,074	41.3	12
PG&E | 2013 | 11	1,119,944	1,103,087	1,122,032	1,065,977	9,028	96,182	342,978	247.9	63
PG&E | 2013 | 12	168,175	166,158	168,425	161,604	1,433	15,267	41,722	29.6	10
PG&E | 2013 | 13	1,033,535	1,019,903	1,035,224	989,112	7,308	77,861	296,716	200.3	51

Installation Group	NPV of System Ownership Cost (PCT) [1]	NPV of System Ownership Cost (TRC, PAC, RIM) [1]	NPV of System Ownership Cost (SCT) [1]	CSI Rebates	NPV of Participant NEBs [2]	NPV of Utility NEBs [3]	First-Year Energy Savings	Installed Capacity	Number of Projects
IOU | Install Year | Climate Zone	$	$	$	$	$	$	kWh/year	kW-DC (STC)	projects
PG&E | 2013 | 2	593,517	585,784	594,475	568,311	4,586	48,854	171,918	113.6	32
PG&E | 2013 | 3	1,707,500	1,685,257	1,710,255	1,635,440	17,196	183,203	484,478	326.6	120
PG&E | 2013 | 4	911,552	899,264	913,074	871,597	8,168	87,021	308,547	180.5	57
PG&E | 2013 | 5	599,410	591,154	600,433	572,535	6,162	65,648	192,716	121.3	43
SCE | 2011 | 10	1,753,399	1,731,619	1,756,151	1,681,881	4,714	171,571	481,570	296.4	80
SCE | 2011 | 13	1,273,280	1,257,251	1,275,305	1,220,073	3,182	115,811	318,857	218.1	54
SCE | 2011 | 15	1,405,343	1,387,490	1,407,598	1,346,212	3,123	113,666	385,325	242.9	53
SCE | 2011 | 6	493,966	487,568	494,774	472,723	2,121	77,207	138,403	87.0	36
SCE | 2011 | 8	846,917	836,172	848,274	811,214	3,123	113,666	228,593	146.2	53
SCE | 2011 | 9	323,592	319,653	324,089	310,510	1,237	45,037	79,638	53.6	21
SCE | 2012 | 10	1,921,662	1,897,147	1,924,759	1,840,174	5,223	199,837	582,981	350.0	91
SCE | 2012 | 13	2,791,927	2,755,849	2,796,485	2,672,590	7,633	292,069	757,103	515.2	133
SCE | 2012 | 14	55,023	54,339	55,109	52,758	172	6,588	21,033	9.8	3
SCE | 2012 | 15	2,757,089	2,722,466	2,761,463	2,642,674	6,198	237,169	820,752	494.4	108
SCE | 2012 | 16	18,023	17,782	18,054	17,228	57	2,196	7,055	3.5	1
SCE | 2012 | 6	753,329	743,694	754,546	721,350	3,157	120,780	222,640	137.6	55
SCE | 2012 | 8	1,129,812	1,116,030	1,131,553	1,084,450	3,788	144,937	319,062	196.8	66
SCE | 2012 | 9	873,727	862,709	875,119	837,100	3,042	116,388	239,989	157.3	53
SCE | 2013 | 10	1,623,849	1,601,933	1,626,617	1,551,106	4,731	185,893	562,514	328.3	83
SCE | 2013 | 13	2,110,050	2,082,358	2,113,548	2,018,788	6,099	239,645	612,873	415.0	107
SCE | 2013 | 14	322,302	318,541	322,777	309,803	912	35,835	102,383	56.3	16

Installation Group	NPV of System Ownership Cost (PCT) [1]	NPV of System Ownership Cost (TRC, PAC, RIM) [1]	NPV of System Ownership Cost (SCT) [1]	CSI Rebates	NPV of Participant NEBs [2]	NPV of Utility NEBs [3]	First-Year Energy Savings	Installed Capacity	Number of Projects
IOU | Install Year | Climate Zone	$	$	$	$	$	$	kWh/year	kW-DC (STC)	projects
SCE | 2013 | 15	1,407,721	1,390,056	1,409,953	1,349,117	3,762	147,818	444,915	264.7	66
SCE | 2013 | 16	96,560	95,235	96,727	92,156	285	11,198	37,094	19.8	5
SCE | 2013 | 6	936,827	925,237	938,291	898,306	3,477	136,620	281,186	173.6	61
SCE | 2013 | 8	1,702,081	1,681,299	1,704,706	1,633,599	5,472	215,009	490,939	311.5	96
SCE | 2013 | 9	615,785	608,479	616,708	591,595	1,938	76,149	162,984	109.5	34
SDG&E | 2011 | 10	581,929	574,354	582,907	556,248	2,775	53,339	167,040	105.3	21
SDG&E | 2011 | 15	29,950	29,604	29,994	28,777	132	2,540	7,903	4.8	1
SDG&E | 2011 | 7	1,216,225	1,201,143	1,218,172	1,165,135	9,516	182,876	334,150	209.7	72
SDG&E | 2012 | 10	560,199	553,545	561,058	537,664	3,358	67,261	160,966	97.1	26
SDG&E | 2012 | 14	76,267	75,359	76,384	73,182	388	7,761	24,190	13.3	3
SDG&E | 2012 | 15	72,627	71,757	72,739	69,672	258	5,174	19,707	12.7	2
SDG&E | 2012 | 7	1,569,181	1,549,695	1,571,696	1,503,430	13,046	261,284	452,378	284.3	101
SDG&E | 2013 | 10	914,553	903,379	915,996	876,684	5,252	108,744	305,055	171.1	41
SDG&E | 2013 | 14	29,732	29,373	29,779	28,512	128	2,652	6,627	5.5	1
SDG&E | 2013 | 7	2,214,028	2,186,344	2,217,602	2,120,031	16,654	344,798	698,599	423.8	130

1. Includes equipment, installation, financing, taxes, O&M, insurance, and inverter replacements costs discounted using the specified cost tests' discount rate.
2. NPV used the PCT discount rate.
3. NPV used the PAC discount rate.

Source: Navigant Consulting, Inc.

Table C-15 provides the SASH avoided retail rates by installation group, which Navigant used in its cost-effectiveness model to calculate the NPV of bill savings. The rates vary by installation group because of different PV output profiles, different mixes of customer rate schedules, and different IOUs.

Table C-15. SASH Avoided Retail Rates by Installation Group ($/kWh)

IOU | Install Year | Climate Zone	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2026	2032
PG&E | 2011 | 1	0.121	0.128	0.132	0.137	0.142	0.150	0.156	0.156	0.159	0.163	0.185	0.216
PG&E | 2011 | 11	0.131	0.138	0.143	0.148	0.154	0.163	0.169	0.169	0.172	0.176	0.200	0.234
PG&E | 2011 | 12	0.112	0.119	0.122	0.127	0.132	0.139	0.145	0.144	0.147	0.151	0.171	0.200
PG&E | 2011 | 13	0.109	0.115	0.119	0.123	0.128	0.135	0.140	0.140	0.143	0.146	0.166	0.194
PG&E | 2011 | 2	0.135	0.143	0.148	0.153	0.159	0.168	0.174	0.174	0.178	0.182	0.207	0.242
PG&E | 2011 | 3	0.119	0.126	0.130	0.135	0.140	0.148	0.153	0.153	0.157	0.160	0.182	0.213
PG&E | 2011 | 4	0.120	0.127	0.131	0.136	0.141	0.149	0.154	0.154	0.158	0.161	0.183	0.214
PG&E | 2011 | 5	0.121	0.128	0.132	0.137	0.142	0.150	0.156	0.156	0.159	0.163	0.184	0.216
PG&E | 2012 | 1	0.126	0.133	0.138	0.143	0.149	0.157	0.163	0.162	0.166	0.170	0.193	0.225
PG&E | 2012 | 11	0.115	0.121	0.125	0.130	0.135	0.143	0.148	0.148	0.151	0.155	0.175	0.205
PG&E | 2012 | 12	0.115	0.122	0.126	0.131	0.136	0.143	0.148	0.148	0.151	0.155	0.176	0.206
PG&E | 2012 | 13	0.123	0.130	0.134	0.139	0.144	0.152	0.158	0.158	0.161	0.165	0.187	0.219
PG&E | 2012 | 2	0.140	0.147	0.152	0.158	0.164	0.173	0.180	0.180	0.183	0.188	0.213	0.249
PG&E | 2012 | 3	0.118	0.125	0.129	0.134	0.139	0.147	0.152	0.152	0.155	0.159	0.180	0.211
PG&E | 2012 | 4	0.131	0.138	0.142	0.148	0.154	0.162	0.168	0.168	0.172	0.176	0.199	0.233
PG&E | 2012 | 5	0.126	0.133	0.137	0.143	0.148	0.156	0.162	0.162	0.166	0.170	0.192	0.225
PG&E | 2013 | 1	0.117	0.124	0.128	0.133	0.138	0.145	0.151	0.151	0.154	0.158	0.179	0.209
PG&E | 2013 | 11	0.109	0.115	0.119	0.124	0.129	0.136	0.141	0.141	0.143	0.147	0.167	0.195
PG&E | 2013 | 12	0.102	0.108	0.111	0.116	0.120	0.127	0.131	0.131	0.134	0.137	0.156	0.182
PG&E | 2013 | 13	0.113	0.119	0.123	0.128	0.132	0.140	0.145	0.145	0.148	0.152	0.172	0.201
PG&E | 2013 | 2	0.117	0.124	0.128	0.133	0.138	0.145	0.151	0.151	0.154	0.158	0.179	0.209

IOU | Install Year | Climate Zone	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2026	2032
PG&E | 2013 | 3	0.115	0.121	0.125	0.130	0.135	0.142	0.148	0.148	0.151	0.154	0.175	0.205
PG&E | 2013 | 4	0.124	0.131	0.135	0.141	0.146	0.154	0.160	0.160	0.163	0.167	0.190	0.222
PG&E | 2013 | 5	0.129	0.136	0.140	0.146	0.151	0.160	0.166	0.165	0.169	0.173	0.196	0.229
SCE | 2011 | 10	0.132	0.137	0.142	0.147	0.151	0.155	0.160	0.165	0.170	0.175	0.209	0.250
SCE | 2011 | 13	0.121	0.124	0.130	0.134	0.137	0.142	0.146	0.150	0.154	0.160	0.190	0.227
SCE | 2011 | 15	0.131	0.135	0.141	0.145	0.149	0.154	0.158	0.163	0.168	0.173	0.207	0.247
SCE | 2011 | 6	0.112	0.116	0.120	0.124	0.128	0.132	0.136	0.140	0.144	0.148	0.177	0.211
SCE | 2011 | 8	0.128	0.132	0.137	0.142	0.145	0.150	0.154	0.159	0.163	0.169	0.202	0.241
SCE | 2011 | 9	0.104	0.107	0.111	0.115	0.118	0.122	0.125	0.129	0.133	0.137	0.164	0.196
SCE | 2012 | 10	0.138	0.143	0.149	0.154	0.158	0.163	0.167	0.172	0.177	0.183	0.219	0.261
SCE | 2012 | 13	0.117	0.121	0.126	0.130	0.133	0.137	0.141	0.146	0.150	0.155	0.185	0.220
SCE | 2012 | 14	0.147	0.152	0.158	0.163	0.168	0.173	0.178	0.183	0.188	0.195	0.232	0.277
SCE | 2012 | 15	0.133	0.137	0.143	0.148	0.151	0.156	0.161	0.166	0.170	0.176	0.210	0.251
SCE | 2012 | 16	0.151	0.156	0.162	0.168	0.172	0.177	0.183	0.188	0.193	0.200	0.239	0.285
SCE | 2012 | 6	0.118	0.122	0.127	0.131	0.135	0.139	0.143	0.147	0.151	0.156	0.187	0.223
SCE | 2012 | 8	0.137	0.142	0.147	0.152	0.156	0.161	0.166	0.171	0.176	0.182	0.217	0.259
SCE | 2012 | 9	0.115	0.119	0.124	0.128	0.131	0.135	0.139	0.143	0.147	0.152	0.182	0.217
SCE | 2013 | 10	0.143	0.148	0.154	0.159	0.163	0.168	0.173	0.178	0.184	0.190	0.226	0.270
SCE | 2013 | 13	0.117	0.121	0.126	0.130	0.134	0.138	0.142	0.146	0.150	0.155	0.186	0.221
SCE | 2013 | 14	0.140	0.144	0.150	0.155	0.159	0.164	0.169	0.174	0.179	0.185	0.221	0.264
SCE | 2013 | 15	0.128	0.132	0.137	0.142	0.145	0.150	0.154	0.159	0.163	0.169	0.202	0.241
SCE | 2013 | 16	0.156	0.161	0.168	0.173	0.178	0.183	0.189	0.195	0.200	0.207	0.247	0.295
SCE | 2013 | 6	0.132	0.136	0.142	0.146	0.150	0.155	0.160	0.164	0.169	0.175	0.208	0.249
SCE | 2013 | 8	0.142	0.147	0.153	0.158	0.162	0.167	0.172	0.177	0.182	0.188	0.225	0.268
SCE | 2013 | 9	0.119	0.123	0.128	0.132	0.136	0.140	0.144	0.149	0.153	0.158	0.189	0.225

IOU | Install Year | Climate Zone	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2026	2032
SDG&E | 2011 | 10	0.201	0.202	0.216	0.224	0.231	0.241	0.248	0.252	0.258	0.265	0.305	0.356
SDG&E | 2011 | 15	0.183	0.183	0.196	0.203	0.210	0.218	0.225	0.229	0.234	0.240	0.277	0.323
SDG&E | 2011 | 7	0.164	0.165	0.176	0.183	0.189	0.196	0.203	0.206	0.210	0.216	0.249	0.291
SDG&E | 2012 | 10	0.183	0.184	0.197	0.204	0.210	0.219	0.226	0.229	0.234	0.241	0.278	0.324
SDG&E | 2012 | 14	0.184	0.185	0.198	0.205	0.211	0.220	0.227	0.230	0.236	0.242	0.279	0.326
SDG&E | 2012 | 15	0.198	0.199	0.213	0.220	0.227	0.237	0.244	0.248	0.254	0.260	0.300	0.351
SDG&E | 2012 | 7	0.160	0.161	0.172	0.178	0.184	0.192	0.198	0.200	0.205	0.211	0.243	0.284
SDG&E | 2013 | 10	0.198	0.198	0.212	0.220	0.227	0.236	0.244	0.247	0.253	0.260	0.299	0.350
SDG&E | 2013 | 14	0.166	0.167	0.178	0.185	0.191	0.199	0.205	0.208	0.212	0.218	0.252	0.294
SDG&E | 2013 | 7	0.179	0.180	0.192	0.199	0.206	0.214	0.221	0.224	0.229	0.236	0.272	0.317

Source: Navigant Consulting, Inc.

Table C-16 presents the SASH levelized avoided costs over the 20-year system lifetime by installation group. These values arise from the multiplication of hourly PV production by the hourly avoided costs for every year within the 20-year PV system lifetime. Navigant then annualized the total lifetime avoided costs and converted them to a $/kWh basis to produce levelized values.

Table C-16. SASH Levelized Avoided Costs over System Lifetime by Installation Group and Cost Test ($/kWh)

IOU | Install Year | Climate Zone	TRC, PCT, PAC, RIM	SCT
PG&E | 2011 | 1	0.130	0.139
PG&E | 2011 | 11	0.119	0.128
PG&E | 2011 | 12	0.120	0.128
PG&E | 2011 | 13	0.124	0.133
PG&E | 2011 | 2	0.124	0.133
PG&E | 2011 | 3	0.120	0.129
PG&E | 2011 | 4	0.117	0.126
PG&E | 2011 | 5	0.133	0.142
PG&E | 2012 | 1	0.137	0.146
PG&E | 2012 | 11	0.127	0.135
PG&E | 2012 | 12	0.123	0.132
PG&E | 2012 | 13	0.128	0.137
PG&E | 2012 | 2	0.128	0.137
PG&E | 2012 | 3	0.124	0.133
PG&E | 2012 | 4	0.123	0.131
PG&E | 2012 | 5	0.135	0.144
PG&E | 2013 | 1	0.145	0.154
PG&E | 2013 | 11	0.134	0.143
PG&E | 2013 | 12	0.131	0.140
PG&E | 2013 | 13	0.134	0.143
PG&E | 2013 | 2	0.136	0.145
PG&E | 2013 | 3	0.131	0.139
PG&E | 2013 | 4	0.127	0.136
PG&E | 2013 | 5	0.143	0.152
SCE | 2011 | 10	0.120	0.130
SCE | 2011 | 13	0.120	0.130
SCE | 2011 | 15	0.119	0.129
SCE | 2011 | 6	0.126	0.135
SCE | 2011 | 8	0.123	0.132
SCE | 2011 | 9	0.123	0.132

IOU | Install Year | Climate Zone	TRC, PCT, PAC, RIM	SCT
SCE | 2012 | 10	0.125	0.135
SCE | 2012 | 13	0.125	0.135
SCE | 2012 | 14	0.113	0.123
SCE | 2012 | 15	0.124	0.134
SCE | 2012 | 16	0.116	0.125
SCE | 2012 | 6	0.130	0.139
SCE | 2012 | 8	0.127	0.137
SCE | 2012 | 9	0.128	0.137
SCE | 2013 | 10	0.132	0.142
SCE | 2013 | 13	0.132	0.142
SCE | 2013 | 14	0.122	0.132
SCE | 2013 | 15	0.130	0.140
SCE | 2013 | 16	0.128	0.137
SCE | 2013 | 6	0.136	0.145
SCE | 2013 | 8	0.134	0.143
SCE | 2013 | 9	0.134	0.144
SDG&E | 2011 | 10	0.125	0.135
SDG&E | 2011 | 15	0.124	0.133
SDG&E | 2011 | 7	0.131	0.140
SDG&E | 2012 | 10	0.132	0.141
SDG&E | 2012 | 14	0.122	0.132
SDG&E | 2012 | 15	0.125	0.135
SDG&E | 2012 | 7	0.137	0.146
SDG&E| 2013 | 10	0.136	0.146
SDG&E| 2013 | 14	0.129	0.138
SDG&E | 2013 | 7	0.143	0.153

Source: Navigant Consulting, Inc.

C.9 MASH COST-EFFECTIVENESS MODEL INPUTS

This section includes the MASH data Navigant used as input to its Analytica-based Cost-Effectiveness Calculator. Although Navigant used output from other tools and pre-processed much of the input data before entering the Calculator, this data's high level of granularity provides additional insight to interested parties. Additionally, stakeholders can use these inputs along with discount rates from Section 2.3.4.1, administrative costs from Section 2.3.3.4, a savings degradation rate of 1.25 percent/year, and an inflation rate of 2 percent/year to re-create our cost test results.

Table C-17 provides the all of the components of the MASH cost tests except the avoided costs and the participant bill savings. These inputs are disaggregated by installation group, which is specified by:

- IOU (PG&E, SCE and SDG&E)
- Installation year (2011, 2012, and 2013)
- Customer type corresponding to the system host (commercial, government and non-profit)
- Ownership type (third-party-owned or host-owned)
- Participant type (owner or tenant)
- Climate zone (1 through 16)

Table C-17. MASH Cost-Effectiveness Inputs by Installation Group

Installation Group	NPV of System Ownership Cost (PCT) [1]	NPV of System Ownership Cost (TRC, PAC, RIM) [1]	NPV of System Ownership Cost (SCT) [1]	CSI Rebates	NPV of Metering Costs [2]	NPV of Participant NEBs [2]	NPV of Utility NEBs [3]	First-Year Energy Savings	Installed Capacity [4]	Number of Projects [4]
IOU | Install Year | Customer Type | Ownership Type | Participant | Climate Zone	$	$	$	$	$	$	$	kWh/year	kW-DC [STC]	projects
PG&E | 2011 | COM | HO | Owner | 3	1,369,035	1,403,769	1,491,730	1,263,405	0	0	0	305,056	454.2	2
PG&E | 2011 | COM | HO | Tenant | 3	0	0	0	0	0	25,917	220,329	425,871		
PG&E | 2011 | COM | HO | Owner | 13	83,512	86,161	93,026	70,554	0	0	0	42,404	25.2	1
PG&E | 2011 | COM | TPO | Owner | 2	290,278	305,853	348,196	184,800	0	0	0	115,780	69.9	3
PG&E | 2011 | COM | TPO | Owner | 3	2,702,716	2,856,912	3,277,479	1,621,685	0	0	0	925,493	584.4	14
PG&E | 2011 | COM | TPO | Owner | 4	1,287,884	1,363,493	1,570,015	749,569	0	0	0	438,243	275.0	6
PG&E | 2011 | COM | TPO | Owner | 11	137,851	147,213	172,957	66,525	0	0	0	41,277	24.8	1
PG&E | 2011 | COM | TPO | Owner | 12	1,326,472	1,392,450	1,571,045	900,781	0	0	0	524,695	315.6	7
PG&E | 2011 | COM | TPO | Owner | 13	1,527,076	1,579,011	1,715,734	1,295,596	0	0	0	220,835	430.1	2
PG&E | 2011 | COM | TPO | Tenant | 13	0	0	0	0	0	13,088	111,266	480,748		
PG&E | 2011 | GOV | HO | Owner | 3	1,444,835	1,310,803	1,451,362	752,262	0	0	0	28,552	236.1	4
PG&E | 2011 | GOV | HO | Tenant | 3	0	0	0	0	0	27,963	237,723	256,964		
PG&E | 2011 | GOV | TPO | Owner | 5	674,407	706,569	793,404	472,831	0	0	0	189,589	148.5	2
PG&E | 2011 | GOV | TPO | Tenant | 5	0	0	0	0	0	2,073	17,626	48,582		
PG&E | 2011 | GOV | TPO | Owner | 11	609,126	630,661	687,545	508,204	0	0	0	0	153.5	1
PG&E | 2011 | GOV | TPO | Tenant | 11	0	0	0	0	0	8,293	70,505	290,301		
PG&E | 2011 | NP | HO | Owner | 3	672,400	718,046	843,724	218,068	0	0	0	122,342	75.9	1
PG&E | 2011 | NP | TPO | Owner | 2	1,975,652	2,044,695	2,226,891	1,656,990	0	0	0	393,145	457.4	10
PG&E | 2011 | NP | TPO | Tenant | 2	0	0	0	0	0	14,384	122,282	329,550		
PG&E | 2011 | NP | TPO | Owner | 3	1,794,496	1,864,181	2,049,670	1,430,284	0	0	0	344,466	403.2	8

Installation Group	NPV of System Ownership Cost (PCT) [1]	NPV of System Ownership Cost (TRC, PAC, RIM) [1]	NPV of System Ownership Cost (SCT) [1]	CSI Rebates	NPV of Metering Costs [2]	NPV of Participant NEBs [2]	NPV of Utility NEBs [3]	First-Year Energy Savings	Installed Capacity [4]	Number of Projects [4]
IOU | Install Year | Customer Type | Ownership Type | Participant | Climate Zone	$	$	$	$	$	$	$	kWh/year	kW-DC [STC]	projects
PG&E | 2011 | NP | TPO | Tenant | 3	0	0	0	0	0	18,653	158,579	276,714		
PG&E | 2011 | NP | TPO | Owner | 11	112,807	120,569	141,927	53,344	0	0	0	36,406	21.4	1
PG&E | 2011 | NP | TPO | Owner | 12	1,742,243	1,833,235	2,080,237	1,136,297	0	0	0	534,674	400.2	4
PG&E | 2011 | NP | TPO | Tenant | 12	0	0	0	0	0	8,812	74,912	83,870		
PG&E | 2011 | NP | TPO | Owner | 13	89,568	95,377	111,318	46,184	0	0	0	29,314	16.9	1
PG&E | 2012 | COM | HO | Owner | 2	265,484	276,824	306,902	188,419	0	0	0	200,861	122.2	1
PG&E | 2012 | COM | HO | Owner | 3	174,633	180,495	195,760	143,579	0	0	0	163,647	92.0	1
PG&E | 2012 | COM | TPO | Owner | 3	353,604	367,512	404,570	279,814	0	0	0	159,308	102.0	1
PG&E | 2012 | COM | TPO | Owner | 4	1,459,942	1,534,866	1,738,049	966,042	0	0	0	431,263	363.3	5
PG&E | 2012 | COM | TPO | Tenant | 4	0	0	0	0	0	7,202	61,414	94,863		
PG&E | 2012 | COM | TPO | Owner | 5	1,264,065	1,329,818	1,508,268	827,074	0	0	0	55,797	253.9	1
PG&E | 2012 | COM | TPO | Tenant | 5	0	0	0	0	0	14,952	127,502	373,411		
PG&E | 2012 | COM | TPO | Owner | 11	263,469	279,257	322,423	149,846	0	0	0	76,224	57.6	2
PG&E | 2012 | COM | TPO | Owner | 12	1,117,779	1,190,063	1,388,406	578,634	0	0	0	196,474	264.8	5
PG&E | 2012 | COM | TPO | Tenant | 12	0	0	0	0	0	13,751	117,256	212,417		
PG&E | 2012 | COM | TPO | Owner | 13	127,253	134,324	153,585	78,378	0	0	0	45,877	28.2	1
PG&E | 2012 | GOV | TPO | Owner | 5	1,366,738	1,415,547	1,544,588	1,134,946	0	0	0	111,583	349.2	2
PG&E | 2012 | GOV | TPO | Tenant | 5	0	0	0	0	0	7,202	61,414	450,392		
PG&E | 2012 | NP | HO | Owner | 3	237,767	253,305	296,085	83,114	0	0	0	80,836	52.2	1
PG&E | 2012 | NP | HO | Owner | 11	1,209,542	1,281,836	1,480,884	489,970	0	0	0	26,197	157.0	1
PG&E | 2012 | NP | HO | Tenant | 11	0	0	0	0	0	6,809	58,059	235,772		

Installation Group	NPV of System Ownership Cost (PCT) [1]	NPV of System Ownership Cost (TRC, PAC, RIM) [1]	NPV of System Ownership Cost (SCT) [1]	CSI Rebates	NPV of Metering Costs [2]	NPV of Participant NEBs [2]	NPV of Utility NEBs [3]	First-Year Energy Savings	Installed Capacity [4]	Number of Projects [4]
IOU | Install Year | Customer Type | Ownership Type | Participant | Climate Zone	$	$	$	$	$	$	$	kWh/year	kW-DC [STC]	projects
PG&E | 2012 | NP | HO | Owner | 12	1,307,897	1,390,671	1,618,576	484,008	0	0	0	18,301	147.8	1
PG&E | 2012 | NP | HO | Tenant | 12	0	0	0	0	0	6,675	56,921	243,141		
PG&E | 2012 | NP | HO | Owner | 13	1,231,995	1,304,485	1,504,076	510,464	0	0	0	23,196	157.9	1
PG&E | 2012 | NP | HO | Tenant | 13	0	0	0	0	0	6,809	58,059	266,752		
PG&E | 2012 | NP | TPO | Owner | 3	2,483,389	2,568,664	2,793,351	2,099,164	0	0	0	0	639.7	1
PG&E | 2012 | NP | TPO | Tenant | 3	0	0	0	0	0	34,710	295,987	1,074,672		
PG&E | 2013 | COM | HO | Owner | 3	441,311	464,275	525,906	262,628	0	0	0	264,757	189.5	4
PG&E | 2013 | COM | HO | Owner | 4	184,096	189,813	204,600	157,037	0	0	0	111,681	69.1	1
PG&E | 2013 | COM | HO | Owner | 5	713,068	728,999	768,703	684,767	0	0	0	511,411	297.5	2
PG&E | 2013 | COM | HO | Owner | 12	590,516	606,290	646,471	535,217	0	0	0	392,069	235.7	1
PG&E | 2013 | COM | HO | Owner | 13	45,651	47,770	53,418	30,331	0	0	0	29,578	20.1	3
PG&E | 2013 | COM | TPO | Owner | 12	2,271,439	2,409,600	2,787,634	1,270,323	0	0	0	106,394	536.9	4
PG&E | 2013 | COM | TPO | Tenant | 12	0	0	0	0	0	32,466	278,501	666,023		
PG&E | 2013 | COM | TPO | Owner | 13	35,720	38,643	46,740	11,860	0	0	0	12,853	9.6	2
PG&E | 2013 | NP | HO | Owner | 2	918,353	978,133	1,142,730	323,320	0	0	0	100,751	159.8	2
PG&E | 2013 | NP | HO | Tenant | 2	0	0	0	0	0	12,641	108,433	157,267		
PG&E | 2013 | NP | HO | Owner | 3	1,065,892	1,142,273	1,352,574	305,653	0	0	0	307,117	197.9	4
PG&E | 2013 | NP | HO | Owner | 4	493,411	527,661	621,961	152,511	0	0	0	136,381	97.3	1
PG&E | 2013 | NP | HO | Owner | 5	154,637	163,035	186,159	71,043	0	0	0	2,547	30.0	1
PG&E | 2013 | NP | HO | Tenant | 5	0	0	0	0	0	2,129	18,262	48,399		
PG&E | 2013 | NP | TPO | Owner | 3	77,822	83,828	100,429	29,767	0	0	0	28,785	19.1	1

Installation Group	NPV of System Ownership Cost (PCT) [1]	NPV of System Ownership Cost (TRC, PAC, RIM) [1]	NPV of System Ownership Cost (SCT) [1]	CSI Rebates	NPV of Metering Costs [2]	NPV of Participant NEBs [2]	NPV of Utility NEBs [3]	First-Year Energy Savings	Installed Capacity [4]	Number of Projects [4]
IOU | Install Year | Customer Type | Ownership Type | Participant | Climate Zone	$	$	$	$	$	$	$	kWh/year	kW-DC [STC]	projects
PG&E | 2013 | NP | TPO | Owner | 13	54,470	58,317	68,914	24,687	0	0	0	26,725	15.3	1
SCE | 2011 | COM | HO | Owner | 14	910,319	935,600	995,760	827,706	0	0	0	520,323	271.3	3
SCE | 2011 | COM | TPO | Owner | 6	429,496	458,318	532,220	225,886	0	0	0	121,062	79.3	5
SCE | 2011 | COM | TPO | Owner | 8	672,827	717,949	833,646	353,975	0	0	0	198,780	128.3	5
SCE | 2011 | COM | TPO | Owner | 9	1,529,386	1,633,317	1,899,964	791,168	0	0	0	500,262	291.5	3
SCE | 2011 | COM | TPO | Owner | 10	411,596	435,885	497,776	250,692	0	0	0	149,375	90.9	2
SCE | 2011 | COM | TPO | Owner | 13	301,434	319,008	363,763	185,787	0	0	0	117,401	68.5	1
SCE | 2011 | COM | TPO | Owner | 14	5,086,834	5,306,455	5,855,428	3,926,601	0	0	0	2,494,565	1,249.8	9
SCE | 2011 | COM | TPO | Owner | 15	583,849	618,018	705,051	358,474	6,047	0	0	49,360	114.3	2
SCE | 2011 | COM | TPO | Tenant | 15	0	0	0	0	0	5,030	65,595	105,777		
SCE | 2011 | GOV | HO | Owner | 6	604,448	537,943	607,749	253,792	2,799	0	0	55,226	82.8	3
SCE | 2011 | GOV | HO | Tenant | 6	0	0	0	0	0	2,263	29,518	62,661		
SCE | 2011 | GOV | TPO | Owner | 6	29,945	31,406	35,088	21,386	0	0	0	12,911	7.6	1
SCE | 2011 | NP | HO | Owner | 6	311,029	328,045	371,846	149,749	0	0	0	77,789	46.4	1
SCE | 2011 | NP | HO | Owner | 15	3,133,380	3,269,053	3,618,301	1,847,416	13,647	0	0	90,237	251.2	1
SCE | 2011 | NP | HO | Tenant | 15	0	0	0	0	0	5,659	73,794	300,399		
SCE | 2011 | NP | TPO | Owner | 14	132,151	141,281	164,724	66,793	0	0	0	50,358	25.1	1
SCE | 2012 | COM | HO | Owner | 8	489,191	504,581	541,681	423,682	0	0	0	325,448	193.7	1
SCE | 2012 | COM | HO | Owner | 9	142,369	146,689	157,064	125,171	0	0	0	67,563	45.1	1
SCE | 2012 | COM | HO | Owner | 10	116,944	120,283	128,253	105,260	0	0	0	61,827	38.6	1
SCE | 2012 | COM | HO | Owner | 14	1,803,086	1,839,178	1,921,371	1,803,119	0	0	0	1,690,241	825.1	2

Installation Group	NPV of System Ownership Cost (PCT) [1]	NPV of System Ownership Cost (TRC, PAC, RIM) [1]	NPV of System Ownership Cost (SCT) [1]	CSI Rebates	NPV of Metering Costs [2]	NPV of Participant NEBs [2]	NPV of Utility NEBs [3]	First-Year Energy Savings	Installed Capacity [4]	Number of Projects [4]
IOU | Install Year | Customer Type | Ownership Type | Participant | Climate Zone	$	$	$	$	$	$	$	kWh/year	kW-DC [STC]	projects
SCE | 2012 | COM | TPO | Owner | 6	880,721	930,527	1,057,155	558,687	0	0	0	368,709	207.3	1
SCE | 2012 | COM | TPO | Owner | 8	4,431,968	4,593,166	4,990,648	3,730,880	7,189	0	0	1,843,541	1,181.9	4
SCE | 2012 | COM | TPO | Tenant | 8	0	0	0	0	0	10,949	143,229	122,319		
SCE | 2012 | COM | TPO | Owner | 9	615,921	646,844	724,923	430,931	3,262	0	0	116,535	127.7	3
SCE | 2012 | COM | TPO | Tenant | 9	0	0	0	0	0	3,297	43,132	90,151		
SCE | 2012 | COM | TPO | Owner | 10	422,785	447,436	510,210	260,587	1,626	0	0	168,873	95.4	3
SCE | 2012 | COM | TPO | Owner | 13	1,158,150	1,230,660	1,415,981	662,718	6,742	0	0	414,325	248.4	8
SCE | 2012 | COM | TPO | Owner | 14	2,304,567	2,424,334	2,727,375	1,570,894	0	0	0	1,088,142	561.5	6
SCE | 2012 | COM | TPO | Owner | 15	1,441,279	1,518,086	1,712,714	962,891	0	0	0	571,880	329.4	6
SCE | 2012 | GOV | HO | Owner | 6	35,727	32,099	35,907	16,598	466	0	0	7,185	8.6	1
SCE | 2012 | GOV | HO | Tenant | 6	0	0	0	0	0	373	4,883	8,038		
SCE | 2012 | GOV | HO | Owner | 9	723,057	640,870	727,137	289,712	0	0	0	212,341	134.4	1
SCE | 2012 | GOV | TPO | Owner | 6	1,832,200	1,874,328	1,972,943	1,794,671	26,422	0	0	218,812	562.9	10
SCE | 2012 | GOV | TPO | Tenant | 6	0	0	0	0	0	14,931	195,313	577,602		
SCE | 2012 | GOV | TPO | Owner | 10	2,232,793	2,303,604	2,475,977	1,986,828	2,544	0	0	591,013	354.1	5
SCE | 2012 | GOV | TPO | Owner | 16	58,931	61,925	69,491	40,861	0	0	0	26,359	15.6	1
SCE | 2012 | NP | TPO | Owner | 6	122,236	129,737	148,889	71,516	0	0	0	30,747	23.0	2
SCE | 2012 | NP | TPO | Owner | 9	737,109	781,785	895,784	436,723	0	0	0	280,008	152.8	5
SCE | 2012 | NP | TPO | Owner | 10	690,327	731,520	836,548	415,628	0	0	0	274,646	145.0	4
SCE | 2013 | COM | HO | Owner | 8	1,214,577	1,280,755	1,446,803	724,847	6,651	0	0	333,806	283.7	2
SCE | 2013 | COM | HO | Tenant | 8	0	0	0	0	0	2,631	34,456	149,871		

Installation Group	NPV of System Ownership Cost (PCT) [1]	NPV of System Ownership Cost (TRC, PAC, RIM) [1]	NPV of System Ownership Cost (SCT) [1]	CSI Rebates	NPV of Metering Costs [2]	NPV of Participant NEBs [2]	NPV of Utility NEBs [3]	First-Year Energy Savings	Installed Capacity [4]	Number of Projects [4]
IOU | Install Year | Customer Type | Ownership Type | Participant | Climate Zone	$	$	$	$	$	$	$	kWh/year	kW-DC [STC]	projects
SCE | 2013 | COM | HO | Owner | 10	2,055,026	2,128,693	2,308,376	1,674,308	19,697	0	0	356,568	563.5	4
SCE | 2013 | COM | HO | Tenant | 10	0	0	0	0	0	27,440	359,329	622,989		
SCE | 2013 | COM | TPO | Owner | 8	855,327	923,210	1,098,494	341,954	0	0	0	250,792	142.1	4
SCE | 2013 | COM | TPO | Owner | 14	381,787	414,842	500,467	124,325	0	0	0	150,017	78.4	2
SCE | 2013 | GOV | HO | Owner | 8	271,112	228,939	273,206	48,750	0	0	0	47,879	32.0	1
SCE | 2013 | GOV | HO | Owner | 9	1,831,704	1,597,075	1,843,351	594,593	0	0	0	539,705	300.1	1
SCE | 2013 | GOV | TPO | Owner | 14	981,313	1,006,542	1,066,507	933,638	15,919	0	0	159,503	293.0	1
SCE | 2013 | GOV | TPO | Tenant | 14	0	0	0	0	0	9,773	127,980	338,944		
SCE | 2013 | NP | HO | Owner | 6	58,045	62,719	74,750	13,746	0	0	0	14,083	9.1	1
SCE | 2013 | NP | HO | Owner | 8	142,653	153,200	180,350	42,685	0	0	0	39,294	25.9	1
SDG&E | 2011 | COM | HO | Owner | 7	265,585	258,725	238,641	408,000	0	0	0	0	53.7	1
SDG&E | 2011 | COM | HO | Tenant | 7	0	0	0	0	0	6,654	69,964	78,101		
SDG&E | 2011 | COM | TPO | Owner | 7	4,053,512	4,175,661	4,450,025	3,732,759	0	0	0	176,621	1,120.2	10
SDG&E | 2011 | COM | TPO | Tenant | 7	0	0	0	0	0	64,699	680,290	1,682,393		
SDG&E | 2011 | COM | TPO | Owner | 10	517,936	554,884	643,269	268,290	0	0	0	170,527	98.7	1
SDG&E | 2011 | NP | HO | Owner | 7	172,919	182,156	204,327	89,628	0	0	0	0	27.6	1
SDG&E | 2011 | NP | HO | Tenant | 7	0	0	0	0	0	2,690	28,283	35,964	27.6	1
SDG&E | 2011 | NP | HO | Owner | 10	727,123	768,491	867,785	354,100	0	0	0	0	106.7	10
SDG&E | 2011 | NP | HO | Tenant | 10	0	0	0	0	0	9,769	102,713	168,852		
SDG&E | 2011 | NP | TPO | Owner | 7	1,547,949	1,605,975	1,739,188	1,313,948	0	0	0	132,665	348.9	3
SDG&E | 2011 | NP | TPO | Tenant | 7	0	0	0	0	0	16,989	178,632	424,068		

Installation Group	NPV of System Ownership Cost (PCT) [1]	NPV of System Ownership Cost (TRC, PAC, RIM) [1]	NPV of System Ownership Cost (SCT) [1]	CSI Rebates	NPV of Metering Costs [2]	NPV of Participant NEBs [2]	NPV of Utility NEBs [3]	First-Year Energy Savings	Installed Capacity [4]	Number of Projects [4]
IOU | Install Year | Customer Type | Ownership Type | Participant | Climate Zone	$	$	$	$	$	$	$	kWh/year	kW-DC [STC]	projects
SDG&E | 2012 | COM | TPO | Owner | 7	845,857	881,382	963,717	680,672	0	0	0	9,845	204.0	3
SDG&E | 2012 | COM | TPO | Tenant | 7	0	0	0	0	0	19,259	203,730	311,832		
SDG&E | 2012 | NP | TPO | Owner | 10	2,493,279	2,627,194	2,942,851	1,721,144	0	0	0	362,252	593.8	3
SDG&E | 2012 | NP | TPO | Tenant | 10	0	0	0	0	0	25,303	267,675	573,228		
SDG&E | 2013 | NP | HO | Owner | 7	260,642	274,439	307,554	136,237	0	0	0	11,145	58.0	1
SDG&E | 2013 | NP | HO | Tenant | 7	0	0	0	0	0	4,808	51,031	81,729		
SDG&E | 2013 | NP | TPO | Owner | 10	986,964	1,056,740	1,223,591	517,401	0	0	0	82,288	231.2	2
SDG&E | 2013 | NP | TPO | Tenant | 10	0	0	0	0	0	17,393	184,612	329,150		

1. Includes equipment, installation, financing, taxes, O&M, insurance, and inverter replacements costs discounted using the specified cost tests' discount rate.
2. NPV used the PCT discount rate.
3. NPV used the PAC discount rate.
4. Some projects allocated savings between owners and tenants, thus there is a single installed capacity value and number of projects associated with the tenant/owner pair.

Source: Navigant Consulting, Inc.

Table C-18 provides the MASH avoided retail rates by installation group, which Navigant used in its cost-effectiveness model to calculate the NPV of bill savings. The rates vary by installation group because of different PV output profiles, different mixes of customer rate schedules, and different IOUs.

Table C-18. MASH Avoided Retail Rates by Installation Group ($/kWh)

IOU | Install Year | Customer Type | Ownership Type | Participant | Climate Zone	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2026	2032
PG&E | 2011 | COM | TPO | Tenant | 13	0.181	0.184	0.191	0.198	0.207	0.214	0.219	0.219	0.222	0.226	0.245	0.272
PG&E | 2011 | COM | TPO | Owner | 2	0.250	0.255	0.264	0.274	0.286	0.296	0.303	0.303	0.307	0.312	0.339	0.376
PG&E | 2011 | COM | TPO | Owner | 3	0.267	0.272	0.282	0.293	0.306	0.317	0.324	0.324	0.328	0.333	0.362	0.402
PG&E | 2011 | COM | TPO | Owner | 4	0.258	0.263	0.272	0.282	0.295	0.306	0.313	0.313	0.317	0.322	0.350	0.388
PG&E | 2011 | COM | TPO | Owner | 11	0.181	0.185	0.191	0.198	0.207	0.214	0.219	0.219	0.222	0.226	0.245	0.272
PG&E | 2011 | COM | TPO | Owner | 12	0.257	0.262	0.271	0.282	0.294	0.305	0.312	0.312	0.316	0.321	0.349	0.387
PG&E | 2011 | COM | TPO | Owner | 13	0.267	0.272	0.282	0.293	0.306	0.317	0.324	0.324	0.328	0.333	0.362	0.402
PG&E | 2011 | COM | HO | Tenant | 3	0.152	0.155	0.161	0.167	0.174	0.180	0.185	0.185	0.187	0.190	0.207	0.229
PG&E | 2011 | COM | HO | Owner | 3	0.268	0.273	0.283	0.294	0.307	0.318	0.325	0.325	0.329	0.334	0.363	0.403
PG&E | 2011 | COM | HO | Owner | 13	0.267	0.272	0.281	0.292	0.305	0.316	0.323	0.323	0.327	0.332	0.361	0.401
PG&E | 2011 | GOV | TPO | Tenant | 5	0.194	0.198	0.205	0.213	0.222	0.230	0.236	0.235	0.239	0.242	0.263	0.292
PG&E | 2011 | GOV | TPO | Tenant | 11	0.176	0.179	0.185	0.192	0.201	0.208	0.213	0.213	0.216	0.219	0.238	0.264
PG&E | 2011 | GOV | TPO | Owner | 5	0.272	0.277	0.287	0.298	0.311	0.322	0.330	0.330	0.334	0.339	0.369	0.409
PG&E | 2011 | GOV | HO | Tenant | 3	0.140	0.143	0.148	0.154	0.161	0.166	0.170	0.170	0.172	0.175	0.190	0.211
PG&E | 2011 | GOV | HO | Owner | 3	0.136	0.139	0.144	0.149	0.156	0.162	0.165	0.165	0.168	0.170	0.185	0.205
PG&E | 2011 | NP | TPO | Tenant | 2	0.146	0.149	0.154	0.160	0.167	0.173	0.177	0.177	0.179	0.182	0.198	0.219
PG&E | 2011 | NP | TPO | Tenant | 3	0.145	0.148	0.153	0.159	0.166	0.172	0.176	0.176	0.178	0.181	0.196	0.218
PG&E | 2011 | NP | TPO | Tenant | 12	0.139	0.142	0.147	0.152	0.159	0.165	0.169	0.169	0.171	0.174	0.189	0.209
PG&E | 2011 | NP | TPO | Owner | 2	0.258	0.263	0.272	0.282	0.295	0.306	0.313	0.313	0.317	0.322	0.350	0.388
PG&E | 2011 | NP | TPO | Owner | 3	0.260	0.265	0.274	0.284	0.297	0.308	0.315	0.315	0.319	0.324	0.352	0.390

IOU | Install Year | Customer Type | Ownership Type | Participant | Climate Zone	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2026	2032
PG&E | 2011 | NP | TPO | Owner | 11	0.247	0.252	0.261	0.271	0.283	0.293	0.300	0.300	0.304	0.308	0.335	0.372
PG&E | 2011 | NP | TPO | Owner | 12	0.259	0.264	0.273	0.283	0.296	0.307	0.314	0.314	0.318	0.323	0.351	0.389
PG&E | 2011 | NP | TPO | Owner | 13	0.237	0.241	0.250	0.259	0.271	0.280	0.287	0.287	0.291	0.295	0.321	0.356
PG&E | 2011 | NP | HO | Owner | 3	0.269	0.274	0.283	0.294	0.307	0.318	0.326	0.326	0.330	0.335	0.364	0.404
PG&E | 2012 | COM | TPO | Tenant | 4	0.141	0.143	0.148	0.154	0.161	0.167	0.170	0.170	0.173	0.175	0.191	0.211
PG&E | 2012 | COM | TPO | Tenant | 5	0.206	0.210	0.217	0.226	0.236	0.244	0.250	0.250	0.253	0.257	0.279	0.310
PG&E | 2012 | COM | TPO | Tenant | 12	0.113	0.115	0.119	0.124	0.129	0.134	0.137	0.137	0.139	0.141	0.153	0.170
PG&E | 2012 | COM | TPO | Owner | 3	0.270	0.275	0.284	0.295	0.308	0.319	0.327	0.327	0.331	0.336	0.365	0.405
PG&E | 2012 | COM | TPO | Owner | 4	0.263	0.268	0.277	0.288	0.301	0.312	0.319	0.319	0.323	0.328	0.357	0.396
PG&E | 2012 | COM | TPO | Owner | 5	0.265	0.270	0.279	0.290	0.303	0.313	0.321	0.321	0.325	0.330	0.359	0.398
PG&E | 2012 | COM | TPO | Owner | 11	0.188	0.191	0.198	0.206	0.215	0.222	0.228	0.228	0.231	0.234	0.254	0.282
PG&E | 2012 | COM | TPO | Owner | 12	0.234	0.238	0.247	0.256	0.268	0.277	0.284	0.283	0.287	0.292	0.317	0.352
PG&E | 2012 | COM | TPO | Owner | 13	0.142	0.144	0.149	0.155	0.162	0.168	0.172	0.172	0.174	0.177	0.192	0.213
PG&E | 2012 | COM | HO | Owner | 2	0.252	0.257	0.265	0.276	0.288	0.298	0.305	0.305	0.309	0.314	0.341	0.378
PG&E | 2012 | COM | HO | Owner | 3	0.272	0.277	0.287	0.298	0.311	0.322	0.330	0.330	0.334	0.339	0.369	0.409
PG&E | 2012 | GOV | TPO | Tenant | 5	0.270	0.276	0.285	0.296	0.309	0.320	0.328	0.328	0.332	0.337	0.366	0.406
PG&E | 2012 | GOV | TPO | Owner | 5	0.271	0.276	0.285	0.297	0.310	0.321	0.328	0.328	0.333	0.338	0.367	0.407
PG&E | 2012 | NP | TPO | Tenant | 3	0.220	0.224	0.232	0.241	0.251	0.260	0.266	0.266	0.270	0.274	0.298	0.330
PG&E | 2012 | NP | HO | Tenant | 11	0.177	0.181	0.187	0.194	0.203	0.210	0.215	0.215	0.218	0.221	0.240	0.267
PG&E | 2012 | NP | HO | Tenant | 12	0.126	0.129	0.133	0.138	0.145	0.150	0.153	0.153	0.155	0.158	0.171	0.190
PG&E | 2012 | NP | HO | Tenant | 13	0.196	0.200	0.207	0.215	0.225	0.233	0.238	0.238	0.241	0.245	0.266	0.295
PG&E | 2012 | NP | HO | Owner | 3	0.100	0.102	0.105	0.109	0.114	0.118	0.121	0.121	0.123	0.125	0.135	0.150
PG&E | 2012 | NP | HO | Owner | 11	0.251	0.256	0.264	0.275	0.287	0.297	0.304	0.304	0.308	0.313	0.340	0.377
PG&E | 2012 | NP | HO | Owner | 12	0.162	0.165	0.170	0.177	0.185	0.191	0.196	0.196	0.198	0.202	0.219	0.243

IOU | Install Year | Customer Type | Ownership Type | Participant | Climate Zone	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2026	2032
PG&E | 2012 | NP | HO | Owner | 13	0.259	0.264	0.273	0.284	0.297	0.307	0.314	0.314	0.318	0.324	0.351	0.390
PG&E | 2013 | COM | TPO | Tenant | 12	0.143	0.146	0.151	0.157	0.164	0.169	0.173	0.173	0.176	0.178	0.194	0.215
PG&E | 2013 | COM | TPO | Owner | 12	0.133	0.135	0.140	0.145	0.152	0.157	0.161	0.161	0.163	0.166	0.180	0.200
PG&E | 2013 | COM | TPO | Owner | 13	0.172	0.175	0.181	0.188	0.197	0.204	0.209	0.208	0.211	0.215	0.233	0.259
PG&E | 2013 | COM | HO | Owner | 3	0.258	0.263	0.272	0.282	0.295	0.305	0.313	0.313	0.317	0.322	0.349	0.388
PG&E | 2013 | COM | HO | Owner | 4	0.264	0.269	0.278	0.289	0.302	0.312	0.320	0.320	0.324	0.329	0.357	0.396
PG&E | 2013 | COM | HO | Owner | 5	0.271	0.276	0.286	0.297	0.310	0.321	0.329	0.329	0.333	0.338	0.368	0.408
PG&E | 2013 | COM | HO | Owner | 12	0.267	0.272	0.281	0.292	0.305	0.316	0.324	0.323	0.328	0.333	0.362	0.401
PG&E | 2013 | COM | HO | Owner | 13	0.211	0.215	0.223	0.231	0.242	0.250	0.256	0.256	0.260	0.264	0.286	0.318
PG&E | 2013 | NP | TPO | Owner | 3	0.263	0.268	0.277	0.288	0.301	0.312	0.319	0.319	0.323	0.328	0.357	0.395
PG&E | 2013 | NP | TPO | Owner | 13	0.257	0.262	0.271	0.282	0.294	0.305	0.312	0.312	0.316	0.321	0.349	0.387
PG&E | 2013 | NP | HO | Tenant | 2	0.095	0.097	0.100	0.104	0.109	0.113	0.115	0.115	0.117	0.119	0.129	0.143
PG&E | 2013 | NP | HO | Tenant | 5	0.194	0.198	0.204	0.212	0.222	0.230	0.235	0.235	0.238	0.242	0.263	0.291
PG&E | 2013 | NP | HO | Owner | 2	0.241	0.246	0.254	0.264	0.276	0.286	0.293	0.293	0.296	0.301	0.327	0.363
PG&E | 2013 | NP | HO | Owner | 3	0.269	0.274	0.283	0.294	0.307	0.318	0.325	0.325	0.330	0.335	0.364	0.404
PG&E | 2013 | NP | HO | Owner | 4	0.124	0.126	0.130	0.135	0.141	0.146	0.150	0.150	0.152	0.154	0.168	0.186
PG&E | 2013 | NP | HO | Owner | 5	0.142	0.145	0.150	0.156	0.163	0.169	0.173	0.172	0.175	0.178	0.193	0.214
SCE | 2011 | COM | TPO | Tenant | 15	0.125	0.129	0.129	0.134	0.137	0.141	0.146	0.150	0.154	0.159	0.190	0.227
SCE | 2011 | COM | TPO | Owner | 6	0.219	0.225	0.226	0.234	0.240	0.248	0.255	0.263	0.270	0.279	0.333	0.397
SCE | 2011 | COM | TPO | Owner | 8	0.214	0.220	0.221	0.228	0.234	0.241	0.249	0.256	0.263	0.272	0.325	0.388
SCE | 2011 | COM | TPO | Owner | 9	0.218	0.224	0.225	0.232	0.238	0.246	0.253	0.261	0.268	0.277	0.331	0.395
SCE | 2011 | COM | TPO | Owner | 10	0.215	0.221	0.222	0.229	0.235	0.242	0.250	0.257	0.264	0.273	0.326	0.389
SCE | 2011 | COM | TPO | Owner | 13	0.212	0.218	0.219	0.226	0.232	0.239	0.246	0.254	0.261	0.269	0.322	0.384
SCE | 2011 | COM | TPO | Owner | 14	0.221	0.227	0.228	0.235	0.242	0.249	0.257	0.264	0.272	0.281	0.335	0.400

IOU | Install Year | Customer Type | Ownership Type | Participant | Climate Zone	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2026	2032
SCE | 2011 | COM | TPO | Owner | 15	0.174	0.179	0.180	0.186	0.190	0.196	0.202	0.208	0.214	0.221	0.264	0.315
SCE | 2011 | COM | HO | Owner | 14	0.221	0.227	0.228	0.235	0.241	0.249	0.256	0.264	0.271	0.280	0.335	0.400
SCE | 2011 | GOV | TPO | Owner | 6	0.154	0.158	0.159	0.164	0.168	0.174	0.179	0.184	0.189	0.196	0.234	0.279
SCE | 2011 | GOV | HO | Tenant | 6	0.152	0.156	0.157	0.162	0.166	0.172	0.177	0.182	0.187	0.193	0.231	0.276
SCE | 2011 | GOV | HO | Owner | 6	0.204	0.209	0.210	0.217	0.223	0.230	0.237	0.244	0.251	0.259	0.309	0.369
SCE | 2011 | NP | TPO | Owner | 14	0.201	0.206	0.207	0.214	0.220	0.227	0.233	0.240	0.247	0.255	0.305	0.364
SCE | 2011 | NP | HO | Tenant | 15	0.178	0.183	0.183	0.189	0.194	0.200	0.206	0.213	0.219	0.226	0.270	0.322
SCE | 2011 | NP | HO | Owner | 6	0.220	0.226	0.227	0.234	0.240	0.248	0.255	0.263	0.270	0.279	0.334	0.398
SCE | 2011 | NP | HO | Owner | 15	0.175	0.180	0.181	0.187	0.192	0.198	0.204	0.210	0.216	0.223	0.266	0.317
SCE | 2012 | COM | TPO | Tenant | 8	0.119	0.123	0.123	0.127	0.131	0.135	0.139	0.143	0.147	0.152	0.181	0.216
SCE | 2012 | COM | TPO | Tenant | 9	0.129	0.133	0.134	0.138	0.141	0.146	0.150	0.155	0.159	0.164	0.196	0.234
SCE | 2012 | COM | TPO | Owner | 6	0.221	0.227	0.228	0.235	0.241	0.249	0.256	0.264	0.272	0.280	0.335	0.400
SCE | 2012 | COM | TPO | Owner | 8	0.218	0.224	0.225	0.233	0.239	0.246	0.254	0.261	0.269	0.278	0.332	0.396
SCE | 2012 | COM | TPO | Owner | 9	0.219	0.225	0.226	0.234	0.240	0.247	0.255	0.262	0.270	0.278	0.332	0.397
SCE | 2012 | COM | TPO | Owner | 10	0.119	0.122	0.123	0.127	0.130	0.134	0.138	0.142	0.146	0.151	0.181	0.216
SCE | 2012 | COM | TPO | Owner | 13	0.210	0.215	0.217	0.224	0.229	0.237	0.244	0.251	0.258	0.267	0.318	0.380
SCE | 2012 | COM | TPO | Owner | 14	0.220	0.226	0.227	0.235	0.241	0.249	0.256	0.264	0.271	0.280	0.334	0.399
SCE | 2012 | COM | TPO | Owner | 15	0.213	0.219	0.220	0.227	0.233	0.240	0.247	0.255	0.262	0.271	0.323	0.386
SCE | 2012 | COM | HO | Owner | 8	0.219	0.225	0.226	0.233	0.239	0.247	0.254	0.262	0.269	0.278	0.332	0.396
SCE | 2012 | COM | HO | Owner | 9	0.218	0.224	0.225	0.232	0.238	0.246	0.253	0.261	0.268	0.277	0.331	0.395
SCE | 2012 | COM | HO | Owner | 10	0.219	0.225	0.226	0.234	0.240	0.248	0.255	0.263	0.270	0.279	0.333	0.397
SCE | 2012 | COM | HO | Owner | 14	0.221	0.227	0.228	0.236	0.242	0.249	0.257	0.264	0.272	0.281	0.335	0.400
SCE | 2012 | GOV | TPO | Tenant | 6	0.185	0.190	0.191	0.197	0.202	0.209	0.215	0.221	0.228	0.235	0.281	0.335
SCE | 2012 | GOV | TPO | Owner | 6	0.215	0.221	0.222	0.229	0.235	0.243	0.250	0.257	0.265	0.273	0.326	0.390

IOU | Install Year | Customer Type | Ownership Type | Participant | Climate Zone	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2026	2032
SCE | 2012 | GOV | TPO | Owner | 10	0.220	0.226	0.227	0.234	0.240	0.248	0.256	0.263	0.271	0.279	0.334	0.398
SCE | 2012 | GOV | TPO | Owner | 16	0.217	0.223	0.224	0.231	0.237	0.244	0.252	0.259	0.266	0.275	0.329	0.392
SCE | 2012 | GOV | HO | Tenant | 6	0.127	0.131	0.131	0.135	0.139	0.143	0.148	0.152	0.156	0.162	0.193	0.230
SCE | 2012 | GOV | HO | Owner | 6	0.209	0.215	0.216	0.223	0.229	0.236	0.243	0.250	0.257	0.266	0.318	0.379
SCE | 2012 | GOV | HO | Owner | 9	0.220	0.226	0.228	0.235	0.241	0.249	0.256	0.264	0.271	0.280	0.334	0.399
SCE | 2012 | NP | TPO | Owner | 6	0.211	0.216	0.217	0.225	0.230	0.238	0.245	0.252	0.259	0.268	0.320	0.382
SCE | 2012 | NP | TPO | Owner | 9	0.221	0.226	0.228	0.235	0.241	0.249	0.256	0.264	0.271	0.280	0.335	0.399
SCE | 2012 | NP | TPO | Owner | 10	0.221	0.227	0.228	0.235	0.242	0.249	0.257	0.264	0.272	0.281	0.335	0.400
SCE | 2013 | COM | TPO | Owner | 8	0.220	0.226	0.227	0.235	0.241	0.248	0.256	0.263	0.271	0.280	0.334	0.399
SCE | 2013 | COM | TPO | Owner | 14	0.219	0.225	0.226	0.233	0.239	0.247	0.254	0.262	0.269	0.278	0.332	0.396
SCE | 2013 | COM | HO | Tenant | 8	0.206	0.211	0.212	0.219	0.225	0.232	0.239	0.246	0.253	0.262	0.312	0.373
SCE | 2013 | COM | HO | Tenant | 10	0.121	0.125	0.125	0.129	0.133	0.137	0.141	0.145	0.149	0.154	0.184	0.220
SCE | 2013 | COM | HO | Owner | 8	0.219	0.225	0.226	0.234	0.240	0.247	0.255	0.262	0.270	0.279	0.333	0.397
SCE | 2013 | COM | HO | Owner | 10	0.221	0.227	0.228	0.236	0.242	0.249	0.257	0.264	0.272	0.281	0.335	0.400
SCE | 2013 | GOV | TPO | Tenant | 14	0.159	0.163	0.164	0.169	0.173	0.179	0.184	0.190	0.195	0.202	0.241	0.287
SCE | 2013 | GOV | TPO | Owner | 14	0.200	0.206	0.207	0.214	0.219	0.226	0.233	0.240	0.246	0.255	0.304	0.363
SCE | 2013 | GOV | HO | Owner | 8	0.220	0.226	0.228	0.235	0.241	0.249	0.256	0.264	0.271	0.280	0.335	0.399
SCE | 2013 | GOV | HO | Owner | 9	0.221	0.227	0.228	0.235	0.242	0.249	0.257	0.264	0.272	0.281	0.335	0.400
SCE | 2013 | NP | HO | Owner | 6	0.216	0.222	0.223	0.230	0.236	0.244	0.251	0.259	0.266	0.275	0.328	0.392
SCE | 2013 | NP | HO | Owner | 8	0.220	0.226	0.227	0.235	0.241	0.249	0.256	0.264	0.271	0.280	0.334	0.399
SDG&E | 2011 | COM | TPO | Tenant | 7	0.210	0.214	0.216	0.224	0.231	0.241	0.248	0.252	0.258	0.265	0.305	0.356
SDG&E | 2011 | COM | TPO | Owner | 7	0.240	0.244	0.247	0.256	0.264	0.275	0.283	0.287	0.294	0.302	0.348	0.407
SDG&E| 2011 | COM | TPO | Owner | 10	0.268	0.272	0.275	0.285	0.294	0.307	0.316	0.321	0.328	0.337	0.389	0.454
SDG&E | 2011 | COM | HO | Tenant | 7	0.141	0.143	0.145	0.150	0.155	0.162	0.167	0.169	0.173	0.178	0.205	0.239

IOU | Install Year | Customer Type | Ownership Type | Participant | Climate Zone	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2026	2032
SDG&E | 2011 | NP | TPO | Tenant | 7	0.204	0.207	0.209	0.217	0.224	0.233	0.240	0.244	0.250	0.256	0.295	0.345
SDG&E | 2011 | NP | TPO | Owner | 7	0.281	0.286	0.289	0.299	0.309	0.322	0.332	0.337	0.344	0.354	0.408	0.476
SDG&E | 2011 | NP | HO | Tenant | 7	0.141	0.143	0.145	0.150	0.155	0.162	0.167	0.169	0.173	0.178	0.205	0.239
SDG&E | 2011 | NP | HO | Tenant | 10	0.143	0.146	0.147	0.153	0.158	0.164	0.169	0.172	0.176	0.181	0.208	0.243
SDG&E | 2012 | COM | TPO | Tenant | 7	0.145	0.147	0.149	0.154	0.159	0.166	0.171	0.173	0.177	0.182	0.210	0.245
SDG&E | 2012 | COM | TPO | Owner | 7	0.139	0.142	0.143	0.148	0.153	0.160	0.165	0.167	0.171	0.175	0.202	0.236
SDG&E | 2012 | NP | TPO | Tenant | 10	0.164	0.166	0.168	0.174	0.180	0.187	0.193	0.196	0.201	0.206	0.237	0.277
SDG&E | 2012 | NP | TPO | Owner | 10	0.276	0.280	0.283	0.294	0.303	0.316	0.325	0.330	0.338	0.347	0.400	0.467
SDG&E | 2013 | NP | TPO | Tenant | 10	0.147	0.149	0.151	0.156	0.161	0.168	0.173	0.176	0.180	0.184	0.213	0.248
SDG&E | 2013 | NP | TPO | Owner | 10	0.236	0.240	0.243	0.251	0.259	0.270	0.279	0.283	0.289	0.297	0.342	0.400
SDG&E | 2013 | NP | HO | Tenant | 7	0.146	0.149	0.150	0.156	0.161	0.167	0.173	0.175	0.179	0.184	0.212	0.248
SDG&E | 2013 | NP | HO | Owner | 7	0.258	0.262	0.265	0.275	0.284	0.296	0.305	0.309	0.316	0.325	0.375	0.438

Source: Navigant Consulting, Inc.

Table C-19 presents the MASH levelized avoided costs over the 20-year system lifetime by installation group. These values arise from the multiplication of hourly PV production by the hourly avoided costs for every year within the 20-year PV system lifetime. Navigant then annualized the total lifetime avoided costs and converted them to a $/kWh basis to produce levelized values.

Table C-19. MASH Levelized Avoided Costs over System Lifetime by Installation Group and Cost Test ($/kWh)

IOU | Install Year | Customer Type | Ownership Type | Participant | Climate Zone	TRC, PCT, PAC, RIM	SCT
PG&E | 2011 | COM | TPO | Tenant | 13	0.108	0.117
PG&E | 2011 | COM | TPO | Owner | 2	0.107	0.116
PG&E | 2011 | COM | TPO | Owner | 3	0.105	0.114
PG&E | 2011 | COM | TPO | Owner | 4	0.105	0.114
PG&E | 2011 | COM | TPO | Owner | 11	0.099	0.108
PG&E | 2011 | COM | TPO | Owner | 12	0.107	0.116
PG&E | 2011 | COM | TPO | Owner | 13	0.108	0.117
PG&E | 2011 | COM | HO | Tenant | 3	0.099	0.108
PG&E | 2011 | COM | HO | Owner | 3	0.101	0.110
PG&E | 2011 | COM | HO | Owner | 13	0.104	0.113
PG&E | 2011 | GOV | TPO | Tenant | 5	0.110	0.119
PG&E | 2011 | GOV | TPO | Tenant | 11	0.104	0.113
PG&E | 2011 | GOV | TPO | Owner | 5	0.100	0.109
PG&E | 2011 | GOV | HO | Tenant | 3	0.101	0.110
PG&E | 2011 | GOV | HO | Owner | 3	0.101	0.110
PG&E | 2011 | NP | TPO | Tenant | 2	0.110	0.119
PG&E | 2011 | NP | TPO | Tenant | 3	0.103	0.112
PG&E | 2011 | NP | TPO | Tenant | 12	0.099	0.108
PG&E | 2011 | NP | TPO | Owner | 2	0.110	0.119
PG&E | 2011 | NP | TPO | Owner | 3	0.105	0.114
PG&E | 2011 | NP | TPO | Owner | 11	0.103	0.111
PG&E | 2011 | NP | TPO | Owner | 12	0.103	0.112
PG&E | 2011 | NP | TPO | Owner | 13	0.111	0.120
PG&E | 2011 | NP | HO | Owner | 3	0.105	0.113
PG&E | 2012 | COM | TPO | Tenant | 4	0.104	0.113
PG&E | 2012 | COM | TPO | Tenant | 5	0.112	0.121
PG&E | 2012 | COM | TPO | Tenant | 12	0.110	0.119
PG&E | 2012 | COM | TPO | Owner | 3	0.113	0.121
PG&E | 2012 | COM | TPO | Owner | 4	0.105	0.114
PG&E | 2012 | COM | TPO | Owner | 5	0.112	0.121

IOU | Install Year | Customer Type | Ownership Type | Participant | Climate Zone	TRC, PCT, PAC, RIM	SCT
PG&E | 2012 | COM | TPO | Owner | 11	0.110	0.119
PG&E | 2012 | COM | TPO | Owner | 12	0.106	0.115
PG&E | 2012 | COM | TPO | Owner | 13	0.113	0.122
PG&E | 2012 | COM | HO | Owner | 2	0.113	0.122
PG&E | 2012 | COM | HO | Owner | 3	0.108	0.117
PG&E | 2012 | GOV | TPO | Tenant | 5	0.113	0.122
PG&E | 2012 | GOV | TPO | Owner | 5	0.113	0.122
PG&E | 2012 | NP | TPO | Tenant | 3	0.110	0.119
PG&E | 2012 | NP | HO | Tenant | 11	0.105	0.115
PG&E | 2012 | NP | HO | Tenant | 12	0.097	0.106
PG&E | 2012 | NP | HO | Tenant | 13	0.110	0.119
PG&E | 2012 | NP | HO | Owner | 3	0.116	0.124
PG&E | 2012 | NP | HO | Owner | 11	0.105	0.115
PG&E | 2012 | NP | HO | Owner | 12	0.097	0.106
PG&E | 2012 | NP | HO | Owner | 13	0.110	0.119
PG&E | 2013 | COM | TPO | Tenant | 12	0.111	0.120
PG&E | 2013 | COM | TPO | Owner | 12	0.109	0.119
PG&E | 2013 | COM | TPO | Owner | 13	0.098	0.108
PG&E | 2013 | COM | HO | Owner | 3	0.115	0.124
PG&E | 2013 | COM | HO | Owner | 4	0.119	0.128
PG&E | 2013 | COM | HO | Owner | 5	0.117	0.126
PG&E | 2013 | COM | HO | Owner | 12	0.108	0.118
PG&E | 2013 | COM | HO | Owner | 13	0.127	0.136
PG&E | 2013 | NP | TPO | Owner | 3	0.117	0.126
PG&E | 2013 | NP | TPO | Owner | 13	0.116	0.125
PG&E | 2013 | NP | HO | Tenant | 2	0.118	0.127
PG&E | 2013 | NP | HO | Tenant | 5	0.116	0.125
PG&E | 2013 | NP | HO | Owner | 2	0.117	0.126
PG&E | 2013 | NP | HO | Owner | 3	0.117	0.126
PG&E | 2013 | NP | HO | Owner | 4	0.114	0.123
PG&E | 2013 | NP | HO | Owner | 5	0.116	0.125
SCE | 2011 | COM | TPO | Tenant | 15	0.104	0.114
SCE | 2011 | COM | TPO | Owner | 6	0.108	0.117
SCE | 2011 | COM | TPO | Owner | 8	0.111	0.120
SCE | 2011 | COM | TPO | Owner | 9	0.106	0.116
SCE | 2011 | COM | TPO | Owner | 10	0.105	0.115

IOU | Install Year | Customer Type | Ownership Type | Participant | Climate Zone	TRC, PCT, PAC, RIM	SCT
SCE | 2011 | COM | TPO | Owner | 13	0.104	0.114
SCE | 2011 | COM | TPO | Owner | 14	0.104	0.114
SCE | 2011 | COM | TPO | Owner | 15	0.104	0.113
SCE | 2011 | COM | HO | Owner | 14	0.103	0.113
SCE | 2011 | GOV | TPO | Owner | 6	0.113	0.123
SCE | 2011 | GOV | HO | Tenant | 6	0.113	0.123
SCE | 2011 | GOV | HO | Owner | 6	0.112	0.122
SCE | 2011 | NP | TPO | Owner | 14	0.102	0.112
SCE | 2011 | NP | HO | Tenant | 15	0.102	0.112
SCE | 2011 | NP | HO | Owner | 6	0.110	0.120
SCE | 2011 | NP | HO | Owner | 15	0.102	0.112
SCE | 2012 | COM | TPO | Tenant | 8	0.117	0.127
SCE | 2012 | COM | TPO | Tenant | 9	0.113	0.123
SCE | 2012 | COM | TPO | Owner | 6	0.113	0.123
SCE | 2012 | COM | TPO | Owner | 8	0.113	0.123
SCE | 2012 | COM | TPO | Owner | 9	0.114	0.124
SCE | 2012 | COM | TPO | Owner | 10	0.113	0.123
SCE | 2012 | COM | TPO | Owner | 13	0.107	0.116
SCE | 2012 | COM | TPO | Owner | 14	0.109	0.119
SCE | 2012 | COM | TPO | Owner | 15	0.109	0.119
SCE | 2012 | COM | HO | Owner | 8	0.114	0.124
SCE | 2012 | COM | HO | Owner | 9	0.127	0.136
SCE | 2012 | COM | HO | Owner | 10	0.108	0.118
SCE | 2012 | COM | HO | Owner | 14	0.106	0.116
SCE | 2012 | GOV | TPO | Tenant | 6	0.117	0.127
SCE | 2012 | GOV | TPO | Owner | 6	0.117	0.127
SCE | 2012 | GOV | TPO | Owner | 10	0.109	0.119
SCE | 2012 | GOV | TPO | Owner | 16	0.104	0.114
SCE | 2012 | GOV | HO | Tenant | 6	0.105	0.115
SCE | 2012 | GOV | HO | Owner | 6	0.105	0.115
SCE | 2012 | GOV | HO | Owner | 9	0.113	0.123
SCE | 2012 | NP | TPO | Owner | 6	0.124	0.134
SCE | 2012 | NP | TPO | Owner | 9	0.112	0.122
SCE | 2012 | NP | TPO | Owner | 10	0.110	0.120
SCE | 2013 | COM | TPO | Owner | 8	0.121	0.131
SCE | 2013 | COM | TPO | Owner | 14	0.114	0.124

IOU | Install Year | Customer Type | Ownership Type | Participant | Climate Zone	TRC, PCT, PAC, RIM	SCT
SCE | 2013 | COM | HO | Tenant | 8	0.116	0.126
SCE | 2013 | COM | HO | Tenant | 10	0.114	0.124
SCE | 2013 | COM | HO | Owner | 8	0.116	0.126
SCE | 2013 | COM | HO | Owner | 10	0.114	0.124
SCE | 2013 | GOV | TPO | Tenant | 14	0.112	0.122
SCE | 2013 | GOV | TPO | Owner | 14	0.112	0.122
SCE | 2013 | GOV | HO | Owner | 8	0.116	0.126
SCE | 2013 | GOV | HO | Owner | 9	0.117	0.127
SCE | 2013 | NP | HO | Owner | 6	0.113	0.124
SCE | 2013 | NP | HO | Owner | 8	0.118	0.128
SDG&E | 2011 | COM | TPO | Tenant | 7	0.110	0.119
SDG&E | 2011 | COM | TPO | Owner | 7	0.110	0.120
SDG&E | 2011 | COM | TPO | Owner | 10	0.107	0.117
SDG&E | 2011 | COM | HO | Tenant | 7	0.118	0.127
SDG&E | 2011 | NP | TPO | Tenant | 7	0.113	0.123
SDG&E | 2011 | NP | TPO | Owner | 7	0.109	0.119
SDG&E | 2011 | NP | HO | Tenant | 7	0.113	0.123
SDG&E | 2011 | NP | HO | Tenant | 10	0.105	0.115
SDG&E | 2012 | COM | TPO | Tenant | 7	0.118	0.128
SDG&E | 2012 | COM | TPO | Owner | 7	0.113	0.122
SDG&E | 2012 | NP | TPO | Tenant | 10	0.114	0.124
SDG&E | 2012 | NP | TPO | Owner | 10	0.113	0.122
SDG&E | 2013 | NP | TPO | Tenant | 10	0.119	0.129
SDG&E | 2013 | NP | TPO | Owner | 10	0.119	0.129
SDG&E | 2013 | NP | HO | Tenant | 7	0.121	0.131
SDG&E | 2013 | NP | HO | Owner | 7	0.121	0.131

Source: Navigant Consulting, Inc.

Appendix D Supplemental Findings Tables

D.1 UTILITY-SPECIFIC PEAK DEMAND REDUCTIONS

In addition to the CAISO peak, Navigant also calculated peak demand impacts based on individual utility system peaks.

Table D-1. Utility Peak Definitions[147]

IOU	Year	Date	Hour Beginning
PG&E	2011	6/21/2011	17
	2012	8/13/2012	17
	2013	7/3/2013	17
SCE	2011	9/7/2011	16
	2012	8/13/2012	15
	2013	9/5/2013	16
SDG&E	2011	9/7/2011	13
	2012	9/14/2012	16
	2013	8/30/2013	16

Source: PA-provided data

Table D-2. Utility Peak Demand Reductions Attributable to Interconnected SASH Systems by IOU

Year	IOU	# of Sites Online	Installed Capacity (kW-AC [CEC])	Demand Reduction (kW-AC [meter])	Peak Capacity Factor
2011	PG&E	170	493	184	37.3%
	SCE	172	506	205	40.5%
	SDG&E	58	168	133	79.1%
2012	PG&E	789	2,510	729	29.1%
	SCE	603	1,862	1,093	58.7%
	SDG&E	188	517	210	40.6%
2013	PG&E	1,315	4,148	1,321	31.9%
	SCE	1,136	3,552	1,249	35.2%
	SDG&E	356	1,032	385	37.3%

Source: Navigant Consulting, Inc.

[147] According to information provided by the PAs during the data requests.

Table D-3. Utility Peak Demand Reductions Attributable to Interconnected MASH Systems by IOU

Year	IOU	# of Sites Online	Installed Capacity (kW-DC [PTC])	Demand Reduction (kW-AC [meter])	Peak Capacity Factor
2011	PG&E	30	1,628	662	40.7%
	SCE	29	2,082	836	40.1%
	SDG&E	24	1,047	821	78.4%
2012	PG&E	85	5,088	1,600	31.4%
	SCE	80	5,364	2,946	54.9%
	SDG&E	31	1,990	806	40.5%
2013	PG&E	106	6,560	2,231	34.0%
	SCE	116	8,207	3,530	43.0%
	SDG&E	34	2,395	944	39.4%

Source: Navigant Consulting, Inc.

D.2 CAPACITY FACTORS BY IOU AND YEAR

Table D-4. SASH Capacity Factor by IOU and Year

IOU	Year	Capacity Factor
PG&E	2011	17.1%
	2012	17.3%
	2013	17.2%
SCE	2011	17.8%
	2012	18.2%
	2013	18.3%
SDG&E	2011	18.2%
	2012	18.4%
	2013	19.2%

Source: Navigant Consulting, Inc.

Table D-5. MASH Capacity Factor by IOU and Year

IOU	Year	Capacity Factor
PG&E	2011	20.9%
	2012	22.9%
	2013	21.3%
SCE	2011	24.0%
	2012	23.0%
	2013	23.1%
SDG&E	2011	21.8%
	2012	20.7%
	2013	23.0%

Source: Navigant Consulting, Inc.