2014 Nonresidential Downstream Deemed ESPI Low-Pressure Sprinkler Nozzle Impact Evaluation Report

Prepared for
California Public Utilities Commission

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Executive Summary

This report documents the activities undertaken by the Nonresidential Downstream Deemed ESPI Impact Evaluation of the 2013-2014 investor-owned utilities' (IOU) energy efficiency programs.[1] The overall goal of this study is to perform an impact evaluation on the deemed savings and measure-parameters associated with the low-pressure irrigation sprinkler nozzle measures that were identified in the Efficiency Savings and Performance Incentive (ESPI) decision.[2]

The objective of this study is to perform a measure and/or measure-parameter impact evaluation, utilizing existing evaluation data and new primary evaluation data, in order to update existing gross and/or net savings estimates and inform future savings values for the sprinkler nozzle measures identified in the ESPI decision. Attachment 2 of the ESPI decision provides an overview of the portfolio parameters that have been identified as potentially requiring ex post verification. The following tasks have been performed by collecting new primary data from participant phone surveys and on-site verification analyses:

- Confirm installations (verification). This step includes on-site verification of measure installations that represent a significant percentage of ex ante claimed electric savings.
- Estimate baseline (pre-retrofit) and replacement (post-retrofit) irrigation pump discharge pressures and operating hours to support more accurate estimate of kWh and kW savings values.
- Estimate participant free-ridership to support the development of net-to-gross ratios and net savings values.
- Based on the above, estimate first year and lifetime gross and net ex post impacts (kWh and kW) for low-pressure sprinkler nozzle measures.

The agricultural irrigation measure category, which includes the conversion to low-pressure sprinkler nozzles, contributes over 1% and 4% to the statewide portfolio's kWh and kW savings, respectively. As low-pressure sprinkler nozzle measures comprised over 70% of total agricultural

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[1] This report focuses on the ESPI measures that were identified for the 2013 program cycle.

[2] D.13.09.023, Decision Adopting Efficiency Savings and Performance Incentive Mechanism. http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M076/K775/76775903.PDF

category kWh and kW savings, the low-pressure sprinkler nozzle measure is the focus of this study.

The evaluation team designed a sampling approach to achieve statistically significant results at the measure level; the sample design was generated using 2013 and 2014 program participants. Per 2013-14 tracking data, the most significant savings are generated from low-pressure sprinkler nozzles installed within the PG&E service territory. As a result, the sample design included only low-pressure sprinkler nozzle projects within PG&E territory. Data collected from 37 phone surveys and 25 on-sites supported this evaluation.

1.1 Overview of Approach

Two distinct evaluation activities were performed, as summarized below.

Gross Energy Savings Analysis. The primary objective of this activity was to develop gross realization rates (GRRs) and net realization rates (NRRs) (ratio between *ex post* and *ex ante* savings) that can be applied to the participant population for the low-pressure sprinkler nozzle measure, such that population estimates of net and gross savings can be estimated for both first year and lifecycle savings. For each sampled project in the analysis, ex post savings were evaluated by separately establishing a number of impact parameters including installation rates, annual operating hours, pumping discharge pressure reduction and coincidence factor. These parameters were estimated based on performing on-site audits on 25 projects at participating farms throughout PG&E territory.

Net-To-Gross Analysis. The objective of this analysis was to develop net-to-gross ratios (NTGRs) for the low-pressure sprinkler nozzle measure group. The approach for estimating NTGRs was based on a self-report methodology utilizing 37 participant survey phone responses. This methodology was based on the large non-residential free ridership approach developed by the NTGR Working Group and documented in Appendix C of that report, *Methodological Framework for Using the Self-Report Approach to Estimating Net-to-Gross Ratios for Nonresidential Customers*. The methodology estimated three separate measurements of free ridership from different inquiry routes and then averaged the values to derive the final free ridership estimate at the measure level.

1.2 Key Findings

Table 1-1 through Table 1-4 present the overall results for this study. Shown are the net and gross, first year, and lifecycle savings realization rates along with the corresponding ex ante and ex post kWh and kW savings for the low-pressure sprinkler nozzle measure for PG&E, as it was the only PA that offered the low-pressure sprinkler nozzle in 2014. The corresponding relative precision and margin of error are also included. Because the GRR is only 2-3%, the relative precision value appears to be very high (since it is proportional to one over the GRR). Therefore, the margin of error is also provided, which is the absolute 90% confidence interval range on either side of the mean. The relative precision is the margin of error divided by the GRR. As is evident from the table, the GRR should be considered a reliable and precise estimate in that its margin of error is 4% or less.[3]

Table 1-1: 2014 Aggregate First Year Gross kWh and kW Realization Rates for PG&E Low-Pressure Sprinkler Nozzle Measure Population

	First Year Gross kWh Savings					First Year Gross kW Savings				
PA	Ex Ante Savings	Ex Post Savings	GRR	Rel. Prec.	Margin of Error	Ex Ante Savings	Ex Post Savings	GRR	Rel. Prec.	Margin of Error
PG&E	14,880,733	464,216	3%	113%	4%	9,686	236	2%	99%	2%

Table 1-2: 2014 Aggregate Lifecycle Ex Post Gross kWh and kW Savings for PG&E Low-Pressure Sprinkler Nozzle Measure Population

	Lifecycle Gross kWh Savings					Lifecycle Gross kW Savings				
PA	Ex Ante Savings	Ex Post Savings	GRR	Rel. Prec.	Margin of Error	Ex Ante Savings	Ex Post Savings	GRR	Rel. Prec.	Margin of Error
PG&E	60,209,089	1,878,269	3%	113%	4%	35,289	861	2%	99%	2%

Table 1-3: 2014 Aggregate First Year Ex Post Net kWh and kW Savings for PG&E Low-Pressure Sprinkler Nozzle Measure Population

	First Year Net kWh Savings					First Year Net kW Savings				
PA	Ex Ante Savings	Ex Post Savings	NRR	Rel. Prec.	Margin of Error	Ex Ante Savings	Ex Post Savings	NRR	Rel. Prec.	Margin of Error
PG&E	8,928,440	153,134	2%	114%	2%	5,811	74	1%	101%	1%

Table 1-4: 2014 Aggregate Lifecycle Ex Post Net kWh and kW Savings for PG&E Low-Pressure Sprinkler Nozzle Measure Population

	Lifecycle Net kWh Savings					Lifecycle Net kW Savings				
PA	Ex Ante Savings	Ex Post Savings	NRR	Rel. Prec.	Margin of Error	Ex Ante Savings	Ex Post Savings	NRR	Rel. Prec.	Margin of Error
PG&E	36,125,453	619,598	2%	114%	2%	21,174	269	1%	101%	1%

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[3] For example, if the GRR was 0.50 and had the same margin of error, the relative precision would be only 8%.

Key reasons behind the 1-3% GRRs and NRRs are described in detail in Section 5.1, but to summarize:

- The IOUs incorrectly classified 19 projects in the sample as involving the installation of portable nozzles; evaluators determined that these projects involved permanent nozzles only. This misclassification resulted in a 60% reduction in overall kWh GRR, due to significantly higher ex ante savings for portable-classified projects as compared with permanent.
- Evaluators determined a weighted average annual operating hours value 64% lower than that reflected within ex ante kWh savings.
- Evaluators determined that, before the low-pressure nozzle installation, 12 sites were irrigated using a method different from the IOU-assumed high-pressure sprinkler method, further reducing the kWh and kW GRRs by 7%.
- Four of the 25 sampled projects were determined to be ineligible for program participation due to: no pre-project electric irrigation at the farm, replacement of low-pressure nozzles with low-pressure nozzles, or replacement of drip irrigation with low-pressure nozzles.
- Section 4.2 indicates a 97% installation rate, further reducing the GRRs by 3%.
- The ex post NTGR was a little more than half of the ex ante value, further reducing the NRRs.

1.3 Key Recommendations

This section presents recommendations based on the findings of this research study. Per the PG&E catalog of 2016 program offerings,[4] the prescriptive low-pressure sprinkler rebate program appears to have been discontinued. However, should the prescriptive program be reinstituted or restructured a custom offering, evaluators recommend the following for more successful program implementation. Additional details behind these recommendations and the evaluation's major findings can be found in Section 6.

Overall Program Design

- If reinstated, incentives for conversions to low-pressure sprinkler irrigation should be offered as a custom measure.

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[4] http://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/Business_Rebates_List.pdf

Eligibility Screening

- If reinstated, the program must perform more careful data collection and screening of applicants to avoid ineligible projects. Evaluators determined that 4 of the 25 sampled projects did not meet the eligibility requirements set forth by the program. Ineligibilities included: one site that did not feature electric irrigation before the project, one project that involved the development of a previously unirrigated field, one project that involved the replacement of low-pressure nozzles with low-pressure nozzles, and one project that involved the replacement of a drip irrigation system with low-pressure nozzles.

Savings Calculations

- If reinstated, the program should sanity-check claimed savings values with the prior year's billed totals to ensure no order-of-magnitude overestimates of savings. Nearly all of the 25 sampled projects had a reported kWh savings claim that exceeded the pre-project annual kWh total from affected utility meter(s).

- If reinstated, the program should utilize an interactive low-pressure nozzle conversion savings calculator that is capable of accounting for the different water requirements of various crop types.

Preexisting Irrigation Method

- The program's savings calculator should account for pre-project irrigation method to accurately predict the resulting change in discharge pressure by converting to low-pressure sprinkler nozzles.

- If reinstated, the program should collect sufficient documentation on nozzle configuration to ensure the portable/permanent classification is correct.

Overall Pumping Efficiency (OPE)

- OPE testing paperwork should be required in the application paperwork to confirm program eligibility and document pumping plant information.

Operating Hours

- If reinstated, the program and its savings calculator should incorporate an annual pumping hours value of 1,163, unless more accurate site-specific operation data is available.

Coincidence Factor

- The program’s savings calculations should incorporate a summer peak coincidence factor of 0.30.

2

Introduction and Overview of Study

This report documents the activities undertaken by the Nonresidential Downstream Deemed ESPI Impact Evaluation of the 2013-2014 IOUs' energy efficiency programs.[5] The overall goal of this study is to perform an impact evaluation on the deemed savings and measure-parameters associated with the low-pressure irrigation sprinkler nozzle measures that were identified in the ESPI decision.[6]

This report is informed by Attachment 2 and 3 of the ESPI decision for program year (PY) 2013 and details the goals and objectives of the impact evaluation to meet those requirements. Likewise, the report will discuss the researchable issues, information on the measure groups evaluated as well as the data sources used, the approach for sampling, the verification analysis and the methods used to determine ex post energy and demand impacts. Finally, the report will present the results and findings from the analysis that can then be used to update the impact parameters, NTGRs and gross/net first year and lifecycle savings for the measures detailed in the ESPI decision.

2.1 Evaluation Research Objectives

The objective of this study is to perform a measure and/or measure-parameter impact evaluation, utilizing new primary evaluation data, in order to update existing gross and/or net savings estimates and inform future savings values for the sprinkler nozzle measures identified in the ESPI decision. Attachment 2 of the ESPI decision provides an overview of the portfolio parameters that have been identified as potentially requiring ex post verification. The parameters associated with deemed measure verification for low-pressure sprinkler nozzles include: measure installation/verification, NTGRs, gross and net energy savings values, annual hours of operation, reduction in pump discharge pressure, and coincidence factor.

In order to implement this approach in meeting the overall study goal, a number of research objectives were targeted. The following tasks have been performed by collecting new primary data from participant phone surveys and on-site verification analyses. A more thorough

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[5] This report focuses on the ESPI measures that were identified for the 2013 program cycle.

[6] D.13.09.023, Decision Adopting Efficiency Savings and Performance Incentive Mechanism. http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M076/K775/76775903.PDF

discussion of how these research objectives are applied to the low-pressure sprinkler nozzle measures and the algorithm by which they have been evaluated are discussed in Section 4, but to summarize:

- Confirm installations (verification). This step includes on-site verification of measure installations that represent a significant percentage of ex ante claimed electric savings.
- Estimate baseline (pre-retrofit) and replacement (post-retrofit) irrigation pump discharge pressures and operating hours to support the estimate of unit energy savings values.
- Estimate participant free-ridership to support the development of NTGRs and net savings values.
- Based on the above, estimate first year and lifetime gross and net ex post impacts (kWh and kW) for low-pressure sprinkler nozzle measures.

2.2 Studied Measure Groups

Table 2-1 presents the agricultural irrigation measure category's (including the low-pressure sprinkler nozzle measure of focus in this study) contribution to each PA's portfolio electric and natural gas energy savings[7] (as well as the statewide contribution) for 2013 and 2014.

Table 2-1: Summary of Deemed ESPI Agricultural Irrigation Measure Category Expressed as a Percentage of each PA's 2013 and 2014 Portfolio Gross Ex Ante Savings

	2013 Savings				2014 Savings			
	SW	PG&E	SCE	SDG&E	SW	PG&E	SCE	SDG&E
kW	4.7%	9.8%	0.0%	0.0%	3.5%	8.2%	0.0%	0.0%
kWh	1.1%	2.4%	0.0%	0.0%	1.1%	2.7%	0.0%	0.0%

As evidenced above in Table 2-1, the agricultural irrigation measure category, which includes the conversion to low-pressure sprinkler nozzles, contributes to the portfolio's kWh and kW savings. As discussed in more detail in Section 3.2, kWh and kW savings from low-pressure sprinkler nozzles is the focus of this study since they comprise over 70% of the ex ante kWh savings within the agricultural irrigation measure category.

Different levels of rigor have been applied to most appropriately assess the performance of the various deemed measures studied to support the ESPI decision. These levels of rigor are informed by the availability and reliability of existing data sources along with the need to gather new primary data. Due to the relatively high contribution of savings to the overall PG&E

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[7] These savings do not include those associated with Codes and Standards.

portfolio, the low-pressure sprinkler nozzle measure was assigned a high level of rigor. As a result, new primary data has been collected utilizing a phone and on-site survey instrument, including the assessment of irrigation pump interval meter data.

2.3 Overview of Impact Evaluation Approach

For low-pressure sprinkler nozzle conversions, the general approach used to estimate ex post gross savings first considered all available data. The challenge in calculating pumping savings is determining the pump head pressure (or associated loading level) of the preexisting irrigation system's pump(s). In order to characterize the pre-conversion pump operation, evaluators relied on pre-project utility bills and interval meter ("smart meter") data when available. However, as many participating farms featured conversions in crop type and/or irrigation method at the time of the nozzle installation, a fair comparison of pre- and post-project utility meter data required normalization by the amount of water delivered before and after the conversion.

Two methods were employed by evaluators, depending on the availability, quality, and comparability of pre/post utility consumption data. However, for every sampled project, the evaluators visited each sampled farm, inspected a selection of rebated nozzles, and collected detailed information on the following parameters (as well as others – see Appendix B) needed to ensure fair pre/post comparison.

Each of the two evaluation methods are described below, in order of preference.

1. Analysis of pre/post electric bills normalized to water consumption

The evaluator's preferred method for assessing project impacts is characterized by the following formula:

$$\frac{\Delta kWh}{yr} = \sum_{i=1}^{12} \left(\frac{kWh}{AF}_{pre,i} - \frac{kWh}{AF}_{post,i}\right) \times AF_{post,i}$$

Where,

$\frac{\Delta kWh}{yr}$ = Annual electric energy savings. This parameter represents the ex post savings objective of this study.

kWh = Monthly electric energy consumption, obtained via data request from the IOU.

AF = Total amount of water delivered to the affected field over each month, in units of *acre-feet*. As many participating farms rely on private well water, not municipally-owned water supply, historic water usage records were typically not available. Instead, field auditors gathered detailed information on field acreage, crop type, crop age, irrigation method, and irrigation schedule (as described above) to calculate the *theoretical* water requirement of the crop. Normalization by the theoretical acre-feet in pre and post cases ensured a fair comparison between pre/post electric consumption.

2. Analysis of project impacts from discharge pressure reduction

When utility consumption data was incomplete or incomparable between pre/post cases, the evaluators assessed project impacts via calculation of the change in pumping power requirement from the low-pressure nozzles' reduction in pumping discharge pressure, as follows:

$$\frac{\Delta kWh}{yr} = \frac{1.0241\ \times (TDH_{pre} - TDH_{post})}{OPE} \times \frac{AF}{yr}$$

$\frac{\Delta kWh}{yr}$ = Annual electric energy savings. This parameter represents the ex post savings objective of this study.

$\frac{AF}{yr}$ = Total acre-feet of water usage per year, as calculated in the previous evaluation method.

TDH_{pre} = Total dynamic head (in feet) of the preexisting irrigation pumping system. This information was not available in PA tracking data; instead, the field auditors estimated this value from customer interviews and information on irrigation method, well depth, theoretical water requirement, and irrigation operating hours.

TDH_{post} = Total dynamic head (in feet) of the installed (low-pressure) irrigation pumping system. Field auditors noted this value via gauge reading, when possible—the affected irrigation pump was often not operating at the time of the site visit. Several farmers monitor this value closely and provided rich information for evaluators to determine a representative value in the savings calculation.

OPE = The pumping system's overall plant efficiency. Participating farms were required to complete an OPE assessment within a year of program application; OPEs of 45% or greater were required for program eligibility. Field staff requested the most recent pump tests that would indicate post-project OPE; however, such records were typically not available from the participating farmers. OPE has been typically estimated by PAs between 45-55% based on field studies.

Non-coincident demand savings (in kW/nozzle) can be calculated using similar equations and parameters presented above.

The remainder of this report will discuss how relevant impact parameters were evaluated for the ESPI low-pressure sprinkler nozzle measure, along with the following:

- Section 3 discusses the data sources that were utilized to estimate each of the individual measure parameters, the sample design, and resulting data used in the evaluation.
- Section 4 presents the methods used for estimating each individual impact parameter, including the installation rate, the pre- and post-project annual operating hours, reduction in irrigation discharge pressure, and the NTGRs.
- Section 5 presents the final study results, including a discussion of the GRRs and NRRs and total population level ex post energy savings values.
- Section 6 presents the conclusions and recommendations.
- Appendix A presents the participant telephone survey instrument.
- Appendix B presents the on-site survey instrument.
- Appendix C presents the phone survey banners.
- Appendix D presents the detailed project-level data and results.
- Appendix AA presents the standardized high level savings for both gross and net first year and lifecycle.
- Appendix AB presents the standardized per unit savings for both gross and net first year and lifecycle.
- Appendix AC presents the summary of recommendations for the Response to Recommendations (RTR).

3

Data Sources, Sample Design, and Data Collection

3.1 Data Sources

A number of data sources were utilized to support the development of each impact parameter in order to update impact parameters, installation rates and NTGRs for the ESPI low-pressure sprinkler nozzle measure researched in this study. As discussed in Section 1, the impacts associated with the sprinkler nozzle measure rely exclusively on new primary on-site data collection: (1) engineering on-site assessments to evaluate the gross impacts associated with those measures and (2) new phone surveys to generate NTGRs. The various sources of data are discussed in more detail below.

3.1.1 On-Site Data Collection

Verification data was collected to support installation rates, farm characteristics (acreage, number of irrigation "sets,"[8] trees per acre), crop characteristics (type, age), irrigation characteristics (pre-project method, frequency, seasonality, typical duration per irrigation), pump characteristics (quantity of affected irrigation pumps, rated horsepower, pump control method, pre/post discharge pressure), and nozzle characteristics (manufacturer, model, casing and nozzle color, and rated flowrate in gpm). A copy of the onsite data collection form has been included as Appendix B.

The onsite also involved collecting spot-reads of pump discharge pressure, when possible; irrigation pumps at sampled farms typically operate at night or on weekends to avoid peak demand charges. Onsites were generally scheduled between April and July to coincide with the growing seasons among the sample of projects. Field staff inspected a selection of nozzles to ensure installation and operability.

In order to ensure fair comparison between pre- and post-project electric usage, the onsite data collection and subsequent site analysis focused on the following five parameters:

- **Crop Type** – Ex ante savings assumptions reflected identical crops in pre and post cases. However, evaluators determined that 10 projects in the sample involved a switch in crop

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[8] An irrigation set is a portion of the total acreage irrigated at a time. For example, a 100-acre farm might rotate irrigating 4 sets of 25 acres to limit the pump horsepower requirement per irrigation.

type at the time of the nozzle installation. Particularly, several farms in the sample converted to water-intensive crops such as almonds and walnuts from less-intensive crops. As different crop types feature different water requirements, this information is highly important to ensure fair pre/post comparison.

- **Crop Age** – For deciduous crops in particular, the older the crop, the more water generally required. As a number of sampled projects involved the planting of young almond or walnut trees at the time of the nozzle installation, data on the age of the trees during pre and post billing periods was crucial in ensuring a fair comparison.
- **Irrigation Method** – Per program workpapers, ex ante savings calculations reflected an assumption of high-pressure sprinkler irrigation before the project. However, evaluators encountered 12 projects in the sample that featured different irrigation methods, such as flood irrigation.
- **Irrigation Patterns –** Information on irrigation frequency (irrigations by month or by season) and irrigation duration (hours irrigated at a time) was collected for pre and post configurations to estimate pre- and post-project annual water requirements.
- **Field Acreage** – Per program eligibility requirements, new (or expanded portions of) farms could not participate in the program. Collection of this acreage information ensured fair normalization by irrigated field size.

3.1.2 Utility Meter Data

The PA provided monthly utility consumption data for all sampled projects and 15-minute interval (“smart meter”) kW data for 15 projects in the sample. The evaluators leveraged this data to characterize pre- and post-project electric usage. Due to the prevalence of smart meter data through June 2015, the evaluators did not perform additional data monitoring at the sample of participating farms.

3.1.3 Participant Phone Survey

A phone survey was conducted to recruit customers for the on-site visit, as well as collect data useful for the NTG analysis and various other components of the evaluation. One other key use of the phone survey was to gather information on annual irrigation schedule and crop type prior to the site visit. This information allowed the field team to strategically schedule the site visits to maximize the chance that the irrigation pump was operating. A copy of the participant phone survey script is included in Appendix A.

3.2 On-Site and Phone Survey Data Collection

As mentioned above, the on-site visits collected data to support a number of the impact parameters including the installation rates, annual operating hours, and reduction in discharge pressure for low-pressure sprinkler nozzle measures. The on-site sample was designed to develop statistically significant results at the measure level. The 2013-14 Nonresidential Downstream Deemed ESPI Impact Evaluation Research Plan[9] for this study discusses the sample design in greater detail, but the resulting design focuses on developing estimates of key impact parameters that can be used to augment existing data in order to update ex ante net and gross kWh and kW savings values for each ESPI measure.

The sample design for low-pressure sprinkler nozzle measures was generated using 2013-14 program participants. According to the ESPI decision, the kWh and kW savings associated with the installation of low-pressure sprinkler nozzles are unclear given uncertainties regarding the varying operating schedules and different discharge pressure requirements of affected irrigation pumps. As presented in Table 2-1, the ex ante statewide kWh and kW savings for agricultural measures represented 1.1% of portfolio level savings. As presented in Table 3-1, the most significant savings are generated from portable sprinkler nozzle installations within PG&E service territory. As a result, the sample design only included sites within PG&E's territory and with low-pressure portable sprinkler nozzles.

Table 3-1: 2013-14 kWh Savings for Agricultural Irrigation Measures by Measure Category and PA

PA	Measure Name	Program Year	Sites	kWh Savings	% kWh Savings
PG&E	sprinkler nozzle low pressure - permanent	2013	21	2,176,700	11%
PG&E	sprinkler nozzle low pressure - permanent	2014	88	7,783,445	36%
PG&E	sprinkler nozzle low pressure - portable	2013	34	11,968,125	62%
PG&E	sprinkler nozzle low pressure - portable	2014	60	7,097,288	33%
PG&E	sprinkler to micro, field/veg	2013	11	1,122,957	6%
PG&E	sprinkler to micro, field/veg	2014	10	225,953	1%
PG&E	sprinkler to micro, no well, deciduous	2013	30	3,623,984	19%
PG&E	sprinkler to micro, no well, deciduous	2014	93	6,585,696	30%
PG&E	sprinkler to micro, vineyard	2013	7	393,778	2%
PG&E	sprinkler to micro, vineyard	2014	1	71,160	0%
SCE	deciduous tree drip irrigation replacing sprinklers	2014	1	53,477	100%
SCE	low pressure sprinkler nozzles - permanent irrigation replacing standard 50+ psi impact-driven spri	2013	1	5,000	100%
SDG&E	agriculture - low pressure sprinkler nozzles (per nozzle)	2013	1	4,515	100%

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[9] http://www.energydataweb.com/cpucFiles/pdaDocs/1210/PY2013-2014%20Deemed%20ESPI%20Research%20Plan_PDA.pdf

Because of the relatively small population of PG&E portable low-pressure sprinkler nozzle participants, a census was attempted. A total of 37 participants were surveyed over the phone, and 25 were visited on-site.

While the sample was originally designed to only consider portable nozzles, the evaluators determined that the IOUs' portable/permanent classifications were not reliable indicators of the actual nozzle configuration observed during site visits. 25 portable-classified projects were selected in the original sample; however, the revised IOU tracking database reclassified 6 of these projects as permanent.[10] Additionally, 19 remaining portable-classified projects were observed by evaluation field staff to be permanent. Table 3-2 indicates the actual nozzle configurations verified by field staff. These differences had implications on the GRR aggregate analysis, as discussed in Section 5.

Table 3-2: Differences between IOU Classification and Verified Sprinkler Nozzle Configuration for On-Site Sample

	Evaluator Findings	
Final IOU Classification	**Permanent**	**Portable**
Permanent	5	1
Portable	19	0
Total	**24**	**1**

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[10] PG&E's program tracking data was finalized after the customers were recruited and on-sites conducted, resulting in some reclassification of installations as being permanent.

4

Evaluation Methodology

This section provides an overview of the methods used to estimate the key impact parameters and the NTGRs for the deemed low-pressure sprinkler nozzle ESPI measure identified for PY 2013-14.

4.1 Overview of Approach

The primary objective of this evaluation is to perform a measure and measure-parameter impact evaluation, utilizing new primary evaluation data, in order to update existing gross and net savings estimates and inform future savings values for the low-pressure sprinkler nozzle measure identified in the ESPI decision. Researched parameters, including operating hours, changes in irrigation pump discharge pressures, installation rates, and estimates of free ridership, can be used to measure ex post performance for PY 2013-14. These parameters are discussed in more detail below. Unless otherwise indicated, all parameter-level averages have been weighted by project sprinkler nozzle count, to ensure that the largest projects are fairly represented.

For low-pressure sprinkler nozzle conversions, the general approach used to estimate ex post gross savings first considered all available data. The challenge in calculating pumping savings is determining the pump head pressure (or associated loading level) of the preexisting irrigation system’s pump(s). In order to characterize the pre-conversion pump operation, evaluators relied on pre-project utility bills and interval meter (“smart meter”) data when available. However, as many participating farms featured conversions in crop type and/or irrigation method at the time of the nozzle installation, a fair comparison of pre- and post-project utility meter data required normalization by the amount of water delivered after the conversion.

Two methods were employed by evaluators, depending on the availability, quality, and comparability of pre/post utility consumption data. However, for every sampled project, the evaluators visited each sampled farm, inspected a selection of incented nozzles, and collected detailed information on the following parameters (as well as others – see Appendix B) needed to ensure fair pre/post comparison.

Each of the two evaluation methods are described below, in order of preference.

1. Analysis of pre/post electric bills normalized to water consumption

The evaluator's preferred method for assessing project impacts is characterized by the following formula:

$$\frac{\Delta kWh}{yr} = \sum_{i=1}^{12} \left(\frac{kWh}{AF}_{pre,i} - \frac{kWh}{AF}_{post,i}\right) \times AF_{post,i}$$

Where,

$\frac{\Delta kWh}{yr}$ = Annual electric energy savings. This parameter represents the ex post savings objective of this study.

kWh = Monthly electric energy consumption, obtained via data request from the IOU.

AF = Total amount of water delivered to the affected field over each month, in units of *acre-feet*. As many participating farms rely on private well water, not municipally-owned water supply, historic water usage records were typically not available. Instead, field auditors gathered detailed information on field acreage, crop type, crop age, irrigation method, and irrigation schedule (as described above) to calculate the *theoretical* water requirement of the crop. Normalization by the theoretical acre-feet in pre and post cases ensured a fair comparison between pre/post electric consumption.

2. Analysis of project impacts from discharge pressure reduction

When utility consumption data was incomplete or incomparable between pre/post cases, the evaluators assessed project impacts via calculation of the change in pumping power requirement from the low-pressure nozzles' reduction in pumping discharge pressure, as follows:

$$\frac{\Delta kWh}{yr} = \frac{1.0241 \times (TDH_{pre} - TDH_{post})}{OPE} \times \frac{AF}{yr}$$

$\frac{\Delta kWh}{yr}$ = Annual electric energy savings. This parameter represents the ex post savings objective of this study.

$\frac{AF}{yr}$ = Total acre-feet of water usage per year, as calculated in the previous evaluation method.

TDH_{pre} = Total dynamic head (in feet) of the preexisting irrigation pumping system. This information was not available in PA tracking data; instead, the field auditors estimated this value from analysis of water table height and well depth, customer interviews, and information on irrigation method and operating hours.

TDH_{post} = Total dynamic head (in feet) of the installed (low-pressure) irrigation pumping system. Field auditors noted this value via gauge reading, when possible— the affected irrigation pump was often not operating at the time of the site visit. Participating farmers typically monitor this value closely and provided rich information for evaluators to determine a representative value in the savings calculation.

OPE = The pumping system's overall plant efficiency. Participating farms were required to complete an OPE assessment within a year of program application; OPEs of 45% or greater were required for program eligibility. Field staff requested the most recent pump tests that would indicate post-project OPE; however, these records were typically not available from the participating farmer. OPE has been typically estimated by PAs between 45-55% based on field studies.

Non-coincident demand savings (in kW/nozzle) can be calculated using similar equations and parameters presented above.

The remainder of this section will focus on the following:

- The approach for estimating each individual impact parameter, including the installation rate, annual operating hours, reduction in pumping discharge pressure, and coincidence factor.
- The approach for estimating the NTGRs.

4.2 Installation Rate Analysis

The installation rate is defined as the percentage of equipment found to be installed and operable. The installation rate is estimated for each site based on data gathered during the on-site visit. As part of these on-site visits, an objective of the auditor was to attempt to identify and assess the quantity and operability of all low-pressure sprinkler nozzles installed.

The key measure count that is identified on site is the quantity of low-pressure sprinkler nozzles that is currently installed and in working condition. Field auditors used a combination of spot inspection, staff interviews, and review of project invoices to confirm the quantity of rebated low-pressure sprinkler nozzles. The installation rate is calculated directly from this measurement:

$$Installation\ Rate = \frac{Count\ of\ low - pressure\ nozzles\ installed\ and\ operable\ from\ onsite\ visit}{Count\ of\ low - pressure\ nozzles\ reported\ installed\ in\ tracking\ system}$$

In addition to identifying the amount of equipment that was installed and operable, the auditor was also prepared to identify the quantity of nozzles that was:

- Failed and in place – The number of nozzles currently installed but not in working condition (failed).
- Failed and replaced – The number of nozzles that had been installed, but then had failed and was replaced with different nozzles.
- Removed and not replaced - The number of nozzles that had been installed, but had been removed (either due to failure or other reasons), but was not replaced, such that sprinkler was currently not irrigating as intended.
- In storage – The number of nozzles that were received but had not yet been installed.

For the 25 sprinkler nozzle projects in the sample, **the field auditors determined an installation rate of 97%**, as one project had not yet installed half of the rebated nozzles. Table 4-1 breaks down the installation rate by the categories defined previously.

Table 4-1: Disposition of ESPI Low-Pressure Sprinkler Nozzle Verification

Measure	Sites	Received Rate	Failure Rate	Storage Rate	Removal Rate	Installation Rate
Sprinkler Nozzle Low-Pressure: Permanent and Portable	25	100%	0.0%	2.6%	0.0%	97.4%

4.3 Operating Hour Analysis

One of the primary inputs to the gross savings calculations is the number of annual hours that the irrigation pump operates. Savings from low-pressure sprinkler nozzles are theoretically realized during each hour of irrigation pump operation. This section will discuss the development of the annual operating hours value from on-site data collection and the analysis of interval data.

For each sampled project, annual operating hours estimates were triangulated among three different calculations, depending on data availability and quality:

1. Interval utility meter data provided 15-minute readings on irrigation pump kW; this data was averaged and extrapolated to estimate the annual operating hours of the pump. An example interval data snapshot is provided in Figure 4-1.

2. Field staff collected information, per the data collection form in Appendix B, on customer-reported irrigation frequency and hours per irrigation, in order to estimate pre- and post-project irrigation pump runtimes.
3. Field staff noted the rated horsepower of affected irrigation pump(s) in the pre- and post-project configurations. If the pump(s) operated at constant speed, the annual utility consumption total divided by the kW rating of the pump(s) results in an estimate of annual full-load operating hours.

Because one or more of the three estimates above might not have encompassed a full year, the operating hour estimates typically needed to be extrapolated out to a full year of 8,760 hours. These extrapolations considered seasonal irrigation patterns and water requirements by crop type. For example, Central Valley farms with deciduous crops typically do not irrigate between the months of November and February.

Figure 4-1: Example Interval Meter Dataset: Hourly kW for June 2013

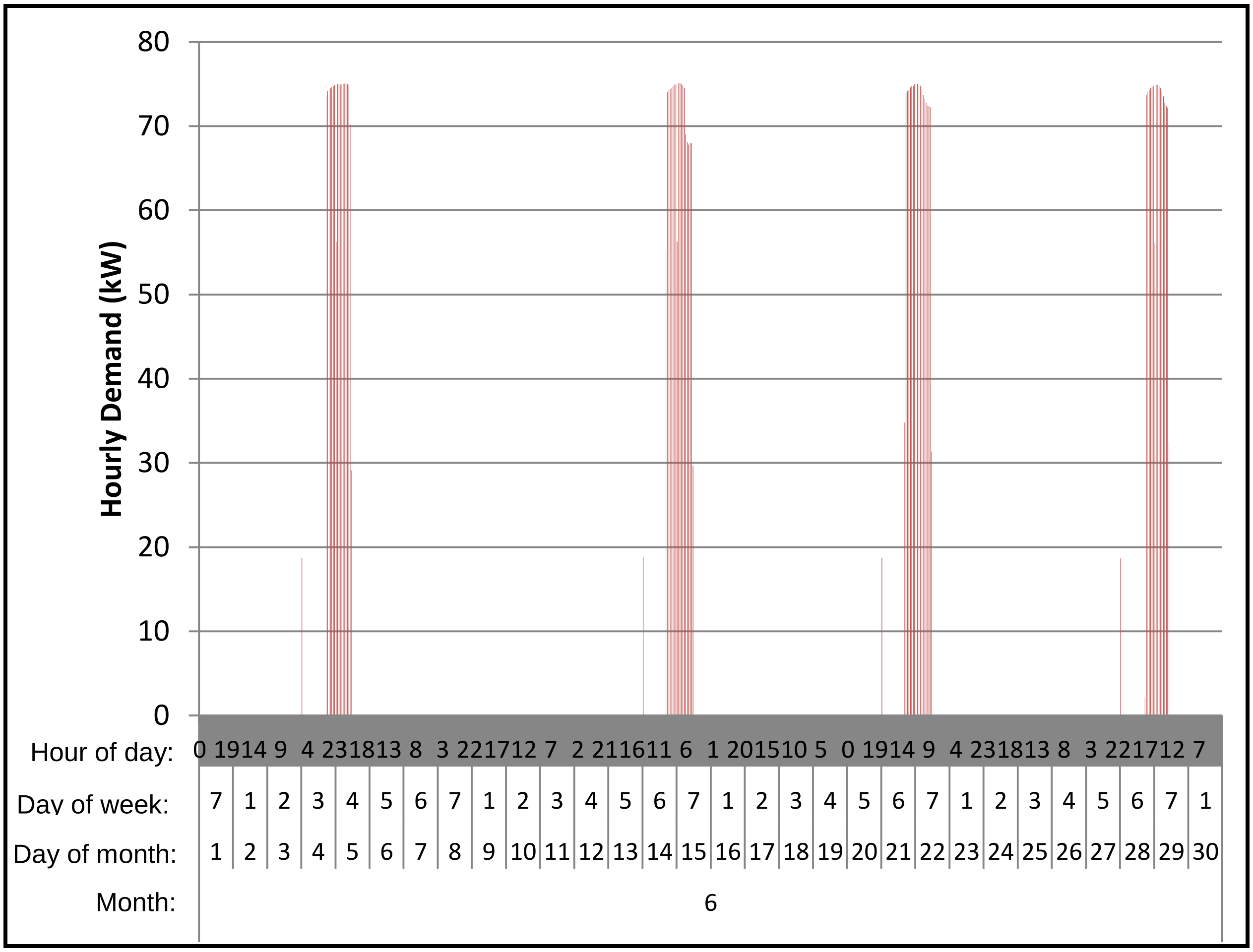

Figure 4-1 illustrates the preference of participating farmers to operate irrigation pumps at night or on weekends to mitigate irrigation water evaporation as well as to avoid peak demand charges (days of week #7 and #1 are Saturdays and Sundays, respectively). After applying the three-pronged operating hours approach described above for each sampled project, the evaluators determined an average irrigation operating hours value weighted by project nozzle quantity. Table 4-2 compares the ex ante operating hours assumption with this ex post finding.

Table 4-2: Comparison of Ex Ante and Ex Post Annual Operating Hours

Measure	Sites	Ex Ante Operating Hours	Ex Post Operating Hours
Sprinkler Nozzle Low-Pressure: Permanent and Portable	21[a]	3,257	1,163

[a] Per Section 1.3, evaluators determined 4 ineligible projects in the sample. These 4 ineligible projects have been excluded from this parameter-level analysis.

Overall, irrigation pumps at participating farms operate 64% fewer hours annually than reflected within ex ante savings assumptions. As 10 sampled projects involved a switch to almond or walnut saplings at the time of the low-pressure sprinkler nozzle installation, young trees generally require less water than full-grown trees, thereby reducing the operating hours of the irrigation pump. While the IOU tracking databases segment the sprinkler nozzle measures into permanent and portable nozzle configurations, our sample indicated that these classifications are not reliable; all projects classified as portable actually involved permanent nozzles. Therefore, we have not segmented the operating hours finding by sprinkler configuration.

4.4 Discharge Pressure Analysis

A key variable affecting the sprinkler nozzle replacement savings is the reduction in discharge pressure experienced by the irrigation pump. Field auditors gathered information on this parameter using two primary methods:

1. Gauge reading of affected irrigation pump(s) in post-project configuration – During site visits to each sampled farm, field staff noted the discharge pressure of the irrigation pump(s) when operating.
2. Customer interviews of pre- and post-project discharge pressures – Farmers typically monitor these values closely, to ensure no overwatering, which can lead to crop disease. Field staff noted their pre/post discharge pressure estimates.

Table 4-3 compares the ex ante discharge pressure reduction assumption with the ex post finding for both permanent and portable nozzles.

Table 4-3: Comparison of Ex Ante and Ex Post Discharge Pressure Reduction

Measure	Sites	Ex Ante Discharge Pressure Reduction	Ex Post Discharge Pressure Reduction
Sprinkler Nozzle Low-Pressure: Permanent and Portable	21[a]	20.0 psi	10.1 psi

[a] Per Section 1.3, evaluators determined 4 ineligible projects in the sample. These 4 ineligible projects have been excluded from this parameter-level analysis.

Overall, affected irrigation pumps experienced a discharge pressure reduction 50% lower than reflected within ex ante savings assumptions. Table 4-4 further examines discharge pressure reduction by pre-project irrigation method. While ex ante savings reflect an assumption of high-pressure sprinkler nozzles in the pre-project configuration, the evaluators determined that only 13 projects in the sample applied this irrigation method.

Table 4-4: Discharge Pressure Reduction by Pre-Project Irrigation Method

Pre-Project Irrigation Method	Sites[1]	Ex Ante Discharge Pressure Reduction	Ex Post Discharge Pressure Reduction
High-pressure sprinkler nozzles	13	20.0 psi	22.1 psi
Flood[2]	8	20.0 psi	-6.2 psi

[1] Per Section 1.3, evaluators determined 4 ineligible projects in the sample. These 4 ineligible projects have been excluded from this parameter-level analysis.

[2] While past program applications could not be found online, an example catalog of program offerings indicates that flood irrigation was an acceptable baseline for low-pressure nozzle eligibility (page 2). http://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/agriculture/AgFood-EM_Agriculture_Irrigation_Fact_Sheet.pdf

Sites that irrigated as the IOUs assumed, via high-pressure sprinkler nozzles, resulted in a discharge pressure reduction 11% greater than assumed in ex ante savings. However, farms that used a flood irrigation method before the project experienced an overall increase in discharge pressure requirement on average at the irrigation pump. With all other parameters equal (e.g., pre/post crop type), an increase in discharge pressure requirement results in an increase in required pumping energy. Therefore, the flood irrigation projects generally resulted in negative impacts.

4.5 Coincidence Factor Analysis

Demand savings realized during the peak coincident period were not anticipated by the IOUs for the low-pressure sprinkler nozzle measure.[11] However, by analyzing the interval utility data for

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[11] Per workpapers and associated savings calculation spreadsheets, a profile of "Nighttime Operation" and CF of 0.00 were assumed within IOU savings estimates.

the 15 sampled farms with smart meters, the evaluators determined that the affected irrigation pumps partially operate during the peak period, as indicated in Table 4-5.

Table 4-5: Comparison of Ex Ante and Ex Post Coincidence Factor

Measure	Sites	Ex Ante Coincidence Factor	Ex Post Coincidence Factor
Sprinkler Nozzle Low-Pressure: Permanent and Portable	15[a]	0.00[b]	0.30

[a] Excludes sites without interval meter data. However, ineligible projects have been included, as their interval data provides valuable information on coincident peak operation; the project's ineligibility would generally not affect the interval operation of the pump in the post-project configuration.

[b] While the tracking database indicates positive nonzero peak demand savings reported by the programs, program workpapers recommend the assumption of a 0.00 peak coincidence factor.

Evaluators determined that affected irrigation pumps are 30% likely to operate during the summer peak coincident period. Several interviewed farmers indicated a preference to irrigate during nights or on weekends to avoid peak demand surcharges and to mitigate the evaporation of irrigation water. However, as irrigation runtimes often exceed 12-18 hours per set, particularly for more water-intensive deciduous crops, it is possible for irrigation pumps to operate into the coincident period.

4.6 Net-to-Gross Analysis

For program years 2013 and 2014, the approach for estimating NTGRs was based on the same approach utilized for the 2010-12 Nonresidential Downstream Lighting Impact Evaluation,[12] which relied solely on participant phone survey data. The NTGR methodology utilized for the 2010-12 Nonresidential Downstream Lighting Impact Evaluation was based on the large nonresidential free ridership approach developed by the NTGR Working Group and documented in Appendix C of that report, *Methodological Framework for Using the Self-Report Approach to Estimating Net-to-Gross Ratios for Nonresidential Customers*. The NTGR is calculated as the average of three program attribution indices (PAI) known as PAI-1, PAI-2, and PAI-3. Each of these scores represents the highest response or the average of several responses given to one or more questions about the decision to install a program measure. The participant phone survey was the basis for the inputs to each score.

- **Program attribution index 1 (PAI–1)** is a score that reflects the influence of the most important of various program-related elements in the customer's decision to select a given program measure. The PAI-1 score is calculated as the highest program influence factor divided by the sum of the highest program influence factor and the highest non-

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[12] http://www.energydataweb.com/cpuc/deliverableView.aspx?did=1155&uid=0&tid=0&cid=

program influence factor. Some example non-program factors are: previous experience with the measure, recommendation from an engineer, standard practice, corporate policy, compliance with rules or regulations, organizational maintenance or equipment replacement policies and “other – specify.” Payback is treated as a program influence factor if the rebate/incentives played a major role in meeting payback criteria, but is treated as a non-program influence factor if it did not play a major role in meeting payback criteria.

- **Program attribution index 2 (PAI–2)** is a score that captures the perceived importance of program factors (including rebate/incentives, recommendation, and training) relative to non-program factors in the decision to implement the specific measure that was eventually adopted or installed. This score is determined by asking respondents to assign importance values to the program and most important non-program influences so that the two total 10. The program influence score is adjusted (i.e., divided by 2) if respondents had made the decision to install the measure before learning about the program. The final score is divided by 10 to be put into decimal form, thus making it consistent with PAI-1.
- **Program attribution index 3 (PAI–3)** is a score that captures the likelihood of various actions the customer might have taken at the given time and in the future if the program had not been available (the counterfactual). This score is calculated as 10 minus the likelihood that the respondent would have installed the same measure in the absence of the program. The final score is divided by 10 to put into decimal form, thus making it consistent with PAI-1 and PAI-2.

The NTGR was estimated as an average of these three scores. If one of the scores was not available (generally due to respondents giving a “don’t know” or “refusal” response), then the NTGR was estimated as the average of the two available score. If two or more scores were missing, results were discarded from the calculation.

Table 4-6 presents the ex ante and ex post NTGR values weighted by ex post kW and kWh savings. Overall, at the statewide level, the ex post NTGR is approximately 52%-55% of the ex ante value. The kWh weighted average program attribution scores for the population were 0.43 for PAI-1, 0.30 for PAI-2 and 0.27 for PAI-3.

Table 4-6: Ex Ante and Ex Post NTGRs by Measure, Weighted by Ex Post kWh

Measure	n[a]	Weight	Ex Ante NTGR	Ex Post NTGR	Relative Precision
Sprinklers	33	kW	0.60	0.31	19%
Sprinklers	33	kWh	0.60	0.33	18%

[a] Per Section 1.3, evaluators determined 4 ineligible projects in the sample. These 4 ineligible projects have been excluded from this analysis.

5

Evaluation Results

This section presents the GRRs and NRRs for first year and lifecycle kWh and kW savings, as well as aggregate ex post population-level savings for first year and lifecycle kWh and kW.

5.1 Gross First Year Realization Rates

GRRs are estimated for kWh and kW savings by looking at the ratio of the aggregate evaluated gross savings to the aggregate ex ante gross savings. Specifically, the GRR is estimated as:

$$Gross\_Realization\_Rate = \frac{\sum_{i=1}^{n} Gross\_Ex\_Post\_Impact_i}{\sum_{i=1}^{n} Gross\_Ex\_Ante\_Impact_i}$$

Where,

> $Gross\_Ex\_Post\_Impact_i$ is the site-specific gross ex post impact estimate for customer i in the population.
>
> $Gross\_Ex\_Ante\_Impact_i$ is the site-specific gross ex ante impact estimate for customer i in the population.

Table 5-1 presents the kWh and kW first year gross realization rates based on the sample of 25 PG&E sites.

Table 5-1: First Year Gross kWh and kW Realization Rates for Low-Pressure Sprinkler Nozzle Measure - PG&E Onsite Sample Results

Measure	Sites	Ex Ante Gross kWh Savings	Ex Post Gross kWh Savings	GRR kWh	Ex Ante Gross kW Savings	Ex Post Gross kW Savings	GRR kW
Sprinkler Nozzle Low-Pressure: Permanent and Portable	25	6,939,165	216,473	3%	5,819	142	2%

As discussed throughout Section 4, the ex post impacts and ex ante claims are products of several unique parameters that are generated in the impact algorithm. The underlying ex ante assumptions regarding each parameter vary by measure as do the ex post impacts. Below is a brief discussion of some of those underlying differences and how they affected the overall realization rates.

- Evaluators determined that 23 of the 25 sampled projects had a reported first-year kWh savings value that exceeded (in some cases, by orders of magnitude) the pre-project annual consumption total from affected utility meter(s). While not an explanation of the GRR in and of itself, this observation provides some context behind the lower-than-expected GRRs.
- The IOUs incorrectly classified 19 projects in the sample as involving the installation of portable nozzles; evaluators determined that these projects involved permanent nozzles only. As the ex ante kWh savings for portable nozzles were nearly four times as high as those for permanent nozzles, this misclassification resulted in a 60% reduction in overall kWh GRR.
- Per Section 4.2, evaluators determined a weighted average annual operating hours value 64% lower than that reflected within ex ante kWh savings. This difference further reduced the kWh GRR by 18%.
- Evaluators determined that, before the low-pressure nozzle installation, 12 sites were irrigated using a method different from the IOU-assumed high-pressure sprinkler method, including 8 flood-irrigated sites. As compared with sprinkler nozzle irrigation, flood irrigation generally requires a lower discharge pressure at the irrigation pump; previously flood-irrigated sites therefore resulted in negative impacts in some cases. As the ex ante savings calculations reflect a conversion from high-pressure to low-pressure nozzles, this difference resulted in lower ex post savings. Overall, differences in pre-project irrigation method resulted in a 7% reduction in GRR.
- Four projects were determined to be ineligible[13] for program participation and therefore resulted in zero savings, driving the GRR down by 7%.
  - One project involved the installation of low-pressure nozzles on a field which featured no electrically-powered irrigation previously.
  - One project involved a field that was not irrigated previously.
  - One project involved replacing low-pressure nozzles with low-pressure nozzles; this is not allowed, per program eligibility requirements.

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[13] As the program is currently inactive, eligibility requirements cannot be cited via web link of the program application. However, per program workpapers and the program measure offering catalog cited in Table 4-4 of this report, evaluators determined that the following eligibility requirements were not met for these four projects: eligible projects must involve previous electrically-irrigated farmland, and only replacements of high-pressure sprinkler or flood irrigation systems are eligible to participate.

  - One project involved converting drip irrigation systems to a low-pressure sprinkler system. Per program eligibility requirements, only high-pressure sprinkler- or flood-irrigated farms were allowed to participate in the program.
- Ten projects involved a switch in crop type at the time of the low-pressure nozzle installation. Due to the growing popularity of almonds and walnuts in the Central Valley, many of these crop switches resulted in a more water-intensive crop at the time of the nozzle installation. As ex ante savings reflect the same crop in pre- and post-project scenarios, this issue resulted in a 3% reduction in GRR.
- Section 4.2 indicates that approximately 3% of rebated nozzles had not yet been installed. The 97% installation rate further reduced the GRRs for kWh and kW.

Table 5-2 presents the first year GRRs along with the corresponding ex ante and ex post first year kWh and kW savings for the low-pressure sprinkler nozzle measure for PG&E, as it was the only PA that offered the low-pressure sprinkler nozzle in 2014. The corresponding relative precision and margin of error are also included. Because the GRR is only 2-3%, the relative precision value appears to be very high (since it is proportional to one over the GRR). Therefore, the margin of error is also provided, which 90% confidence interval range on either side of the mean. The relative precision is the margin of error divided by the GRR. As is evident from the table, the GRR should be considered a reliable and precise estimate in that its margin of error is 4% or less.[14]

Table 5-2: 2014 Aggregate First Year Gross kWh and kW Realization Rates for PG&E Low-Pressure Sprinkler Nozzle Measure Population

	First Year Gross kWh Savings					First Year Gross kW Savings				
PA	**Ex Ante Savings**	**Ex Post Savings**	**GRR**	**Rel. Prec.**	**Margin of Error**	**Ex Ante Savings**	**Ex Post Savings**	**GRR**	**Rel. Prec.**	**Margin of Error**
PG&E	14,880,733	464,216	3%	113%	4%	9,686	236	2%	99%	2%

5.2 Lifecycle Gross Realization Rates

Table 5-3 presents the lifecycle GRRs along with the corresponding ex ante and ex post first year kWh and kW savings for the low-pressure sprinkler nozzle measure. Lifecycle savings values are equal to the first year savings multiplied by the EUL. Because this study did not evaluate the EULs, the ex ante EUL was used. Therefore, first year and lifecycle realization rates are the same.

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[14] For example, if the GRR was 0.50 and had the same margin of error, the relative precision would be only 8%.

Table 5-3: 2014 Aggregate Lifecycle Ex Post Gross kWh and kW Savings for PG&E Low-Pressure Sprinkler Nozzle Measure Population

	Lifecycle Gross kWh Savings					Lifecycle Gross kW Savings				
PA	**Ex Ante Savings**	**Ex Post Savings**	**GRR**	**Rel. Prec.**	**Margin of Error**	**Ex Ante Savings**	**Ex Post Savings**	**GRR**	**Rel. Prec.**	**Margin of Error**
PG&E	60,209,089	1,878,269	3%	113%	4%	35,289	861	2%	99%	2%

5.3 Net First Year Realization Rates

Net savings are estimated in a manner similar to the gross savings. NRRs are estimated for kWh and kW savings by looking at the ratio of the aggregate evaluated gross savings to the aggregate ex ante gross savings. Specifically, the NRR is estimated as:

$$Net\_Realization\_Rate \quad = \frac{\sum_{i=1}^{n} Net\_Ex\_Post\_Impact_i}{\sum_{i=1}^{n} Net\_Ex\_Ante\_Impact_i}$$

Where,

> $Net\_Ex\_Post\_Impact_i$ is the site-specific net ex post impact estimate for customer i in the population
>
> $Net\_Ex\_Ante\_Impact_i$ is the site-specific net ex ante impact estimate for customer i in the population.

Table 5-4 presents the kWh and kW first year NRRs.

Table 5-4: 2014 Aggregate First Year Ex Post Net kWh and kW Savings for PG&E Low-Pressure Sprinkler Nozzle Measure Population

	First Year Net kWh Savings					First Year Net kW Savings				
PA	**Ex Ante Savings**	**Ex Post Savings**	**NRR**	**Rel. Prec.**	**Margin of Error**	**Ex Ante Savings**	**Ex Post Savings**	**NRR**	**Rel. Prec.**	**Margin of Error**
PG&E	8,928,440	153,134	2%	114%	2%	5,811	74	1%	101%	1%

The NRRs differ for the same reasons discussed above for GRRs; however, they are also influenced by differences between ex post and ex ante NTGRs. The ex post NTGRs are less than ex ante NTGRs (about 52-55% of ex ante), which explains why NRRs are lower than GRRs.

5.4 Lifecycle Net Realization Rates

Lifecycle NRRs are estimated in a similar way as lifecycle GRRs, by looking at the ratio of the evaluated ex post net lifecycle savings to the ex ante net lifecycle savings. The approach is identical to that for the lifecycle GRRs, but using net savings instead of gross. As with the first year values, the lifecycle NRRs in Table 5-5 are the same as the first-year NRRs in Table 5-4.

Table 5-5: 2014 Aggregate Lifecycle Ex Post Net kWh and kW Savings for PG&E Low-Pressure Sprinkler Nozzle Measure Population

	Lifecycle Net kWh Savings					Lifecycle Net kW Savings				
PA	**Ex Ante Savings**	**Ex Post Savings**	**NRR**	**Rel. Prec.**	**Margin of Error**	**Ex Ante Savings**	**Ex Post Savings**	**NRR**	**Rel. Prec.**	**Margin of Error**
PG&E	36,125,453	619,598	2%	114%	2%	21,174	269	1%	101%	1%

6

Conclusions and Recommendations

This section presents conclusions and subsequent recommendations based on the findings of this research study. Per the PG&E catalog of 2016 program offerings,[15] the prescriptive low-pressure sprinkler rebate appears to have been discontinued. However, should the prescriptive program be reinstituted or restructured as a custom offering, evaluators recommend the following for improved program delivery.

Conclusion 1 [Section 5.1]: Agricultural irrigation projects are difficult to accurately characterize with deemed savings values. Due to its prescriptive delivery mechanism, the low-pressure nozzles program was unaware of several key variables that affect savings at the irrigation pump. Nearly each of the 25 sampled projects was a unique permutation of the following variables not previously considered in the program deemed savings calculation: pre-project crop type, pre-project crop age, pre-project irrigation method, and pre-project field size. Each of these variables can significantly affect irrigation requirements and subsequent savings from low-pressure nozzle installation. Many of the conclusions and recommendations below provide more insight into how the IOUs might better characterize these variables and avoid savings overestimates in the future.

Recommendation 1: If reinstated, incentives for conversions to low-pressure sprinkler irrigation should be offered as a custom measure. A custom savings approach could more comprehensively gather the site-specific data needed to not only confirm measure eligibility, but also ensure that the subsequent ex ante savings are accurate.

Conclusion 2 [Section 5.1]: Four of the 25 sampled projects were determined to be ineligible for program participation. Of these 4 projects, 1 involved farmland without electric irrigation before the nozzle rebate, 1 involved the development of a previously unirrigated field, 1 involved a replacement of low-pressure nozzles with low-pressure nozzles, and 1 involved the replacement of a drip irrigation system with low-pressure nozzles.

Recommendation 2: If reinstated, the program must perform more careful data collection and screening of applicants to avoid ineligible projects. The initial application process should

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[15] http://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/Business_Rebates_List.pdf

include documented proof of the following: existing crop type and age, planned crop type, existing irrigation method, as well as relevant photographs and a prior year's worth of electric billing data for the affected irrigation pump.

Conclusion 3 [Section 5.1]: Twenty-three of the 25 sampled projects featured an ex ante first-year kWh savings value that exceeded the pre-project annual electric consumption of the affected pump(s). In some cases, the ex ante kWh savings exceeded the pre-project annual electric consumption by a factor of 10 or more. Several projects featured an ex ante kW savings value that exceeded the connected kW of affected irrigation pumps.

Recommendation 3: If reinstated, the program should sanity-check claimed savings values with the prior year's billed totals to ensure no order-of-magnitude overestimates of savings. This information should be made available per the application requirements of Recommendation 2.

Conclusion 4 [Section 5.1]: Ten of the 25 sampled projects involved a switch in crop type at the time of the low-pressure nozzle installation. Due to the increasing popularity of almonds and walnuts worldwide, all of the 10 conversions resulted in a switch to one of these more water-intensive crops. As the previous growth is typically razed as a part of the crop switch, many participating farmers saw the crop switch as an opportunity to install a new irrigation system. Higher water requirements lead to higher irrigation pumping requirements and possible increases in electric consumption. However, since farmers were very likely to convert their crops regardless of program intervention, the ex post savings are normalized for the higher water requirement of the post-project crop in the pre-project annual kWh consumption calculation.

Recommendation 4: If reinstated, the program should utilize an interactive low-pressure nozzle conversion savings calculator that can account for the different water requirements of various crop types. The evaluation team developed such a calculator, which incorporates crop-specific water requirement data, allowing fair comparison between pre- and post-project conditions. Additionally, the program's screening tool should incorporate information on customer decision-making absent the program, specifically in instances of crop switches, field expansions, or pump replacements, to determine a counterfactual baseline on which savings are based.

Conclusion 5 [Section 5.1]: Twelve of the 25 sampled projects involved a pre-project irrigation method different from that reflected in ex ante savings assumptions. Of these 12 projects, 8 involved flood irrigation in the pre-project case. On the other hand, the ex ante savings reflected high-pressure sprinkler irrigation in the preexisting configuration. While flood irrigation is generally less water-efficient than sprinkler irrigation, the pumping discharge pressure requirement is generally lower for flood irrigation as compared with sprinkler irrigation. Pumps supporting flood irrigation must overcome only the static pressure requirement of drawing the water from the well. Lower discharge pressure requirements result in lower electric demand for the flood irrigation pump(s) and, depending on flooding frequency and duration, lower electric consumption as compared with sprinkler irrigation.

Recommendation 5: The program's savings calculator (recommended in #4) should account for pre-project irrigation method to accurately predict the resulting change in discharge pressure by converting to low-pressure sprinkler nozzles. Recommendation #7 below provides guidance on how the program might acquire the necessary up-to-date pumping information for participation in the program.

Conclusion 6 [Section 5.1]: All of the 19 sampled projects classified as "portable" actually involved the installation of permanent nozzles. Ex ante kWh savings for portable nozzles are approximately four times higher than for permanent nozzles. This misclassification resulted in significantly lower ex post savings.

Recommendation 6: If reinstated, the program should collect sufficient documentation on nozzle configuration to ensure the portable/permanent classification is correct. Sufficient documentation includes photographs of the preexisting system and invoices of previously installed nozzles and piping.

Conclusion 7: Nearly all of the sampled participants could not produce operating pumping efficiency (OPE) paperwork required for participation in the prescriptive program. OPE greatly affects savings from the discharge pressure reduction, per the formula in Section 2.3. Per program workpapers, eligible irrigation pumps must feature an OPE of 0.45 or above.

Recommendation 7: OPE testing paperwork must be included with the application paperwork to confirm program eligibility and document pumping plant information. PG&E, for example, provides subsidies for such tests.

Conclusion 8 [Section 4.3]: Irrigation pumps were found to operate 1,163 hours annually. This value is 64% lower than the 3,257 annual hours reflected in ex ante savings assumptions. As several projects involved a crop switch to young almond or walnut trees at the time of the low-pressure nozzle installation, the young trees generally require less water than full-grown trees, leading to lower irrigation pump operating hours than anticipated.

Recommendation 8: If reinstated, the program and its savings calculator should incorporate an annual pumping hours value of 1,163. However, the savings calculator should be sufficiently customizable to incorporate more site-specific data on operating conditions as it becomes available.

Conclusion 9 [Section 4.5]: Though not anticipated by the program to result in peak demand savings, the sampled irrigation pumps were 30% likely to operate during the summer coincident peak period. Evaluators assessed 15 sets of utility interval meter data among the 25 sampled projects to determine this average value weighted by project nozzle quantity. Though many participating farmers try to irrigate during nights or weekends to avoid peak demand charges, certain crops (particularly full-grown trees) are irrigated for periods exceeding 18 hours, inevitably leading to some irrigation occurring during the peak period. Though program tracking databases indicate positive, nonzero peak demand savings for each sampled project, program workpapers recommend that ex ante demand savings should reflect a coincidence factor assumption of 0.00 due to a "night operation" classification.

Recommendation 9: The program's savings calculations should incorporate a summer peak coincidence factor of 0.30. This revision would lead to more accurate claims of peak demand savings.