Making Impact Evaluations More Impactful: A California Collaboration the Nation can Adopt

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ABSTRACT

Impact evaluations serve diverse stakeholder groups, each with different needs, level of technical understanding, and discretionary time. As energy efficiency (EE) enters the evolving integrated distributed energy resources paradigm the impact evaluation audience will expand even further. For EE to succeed, evaluations must effectively reach the full readership. This paper describes big steps California is taking toward making impact evaluations more consistent, comparable and accessible, both for technical and non-technical audiences. We focus on three recent and related projects that are improving evaluation reporting and EE data quality: 1. The Impact Evaluation Standard Reporting guidelines, which were adopted in 2015 and ensure complete and consistent reporting of savings, realization rates and recommendations; 2. The Energy Savings and Performance Incentive database, which provides users a claim-level, queryable dataset with complete ex ante and ex post information; 3. Development of order-independent waterfall graphics to give readers a concise, accurate, and quantitative visual breakdown of savings and ex ante/ex post discrepancies. The structural foundation for savings claims and impact evaluations has also been the focus of a multiyear evolution, resulting in the California Energy Data and Reporting System, which automates data quality control. Each of these resources is publicly available and can help organizations across the country encourage full utilization of data and research among the broadest possible audience. Finally, we propose a structure for a four-page summary to clearly describe methods and showcase key results for decision makers who are unlikely to dive deeper into a report.

Introduction

Energy efficiency (EE) has long been recognized as a vital tool to meet state emissions targets, keep energy costs reasonable for customers, and limit unnecessary waste. There is little doubt that these goals will remain important going forward. But EE must evolve to meet a new set of demands emerging from a rapidly changing energy industry. New dynamics are on the horizon that will impact EE and associated reporting needs, including,

- Energy efficiency is being considered as a procurement mechanism. Within this context, EE will be in competition with traditional generation as well as other distributed energy resources

(CPUC 2016).[1] For EE to be utilized to its full potential, data and evaluations will be needed that provide "apples to apples" comparisons among distinct energy resources.

- The time value of electricity and EE savings are becoming increasingly variable as greater intermittent generation from renewables, along with growing evening demand, creates a more dynamic system load.
- More stringent federal emissions standards and aggressive EE targets are logical next steps in meeting international climate change goals. In 2015 the Clean Power Plan (CPP), established by the United States Environmental Protection Agency was released (U.S. EPA 2015). Among other directives, the CPP would allow states to use EE to meet emissions targets. Though currently pending judicial review and a politically challenging environment, the CPP is evidence of the potential for federal EE goals. Consistent EM&V methods and reporting will be essential to gauge the success of broad reaching EE and climate change targets.

For EE to effectively rise to these new challenges, evaluation must adapt. In particular, impact evaluations must reach an expanding audience with both comprehensive reporting and effective high level summaries. Important constituencies now include program administrators and managers, regulators, policy makers, procurement planners, ratepayers, and other public stakeholders. Each of these groups has unique needs and levels of EE and EM&V understanding.

For any audience, an impact evaluation should provide clear answers to a few core questions: 'How did savings predictions compare with evaluated results?' and 'What were the important drivers of any discrepancies?' In light of the growing and diversifying EE goals and evaluation audience, a renewed focus on how we approach these fundamental questions is needed. Here we describe steps California is taking to enhance impact evaluation reporting and data across the lifecycle of EE programs. We focus primarily on three projects that collectively are helping ensure results are fully utilized:

- Impact Evaluation Standard Reporting (IESR) guidelines – The IESR guidelines standardize reporting of savings and realization rates, early retirement findings, and recommendations.
- The Energy Savings and Performance Incentive (ESPI) database –The ESPI database is a portfolio-wide, queryable, claim-level database with complete information in both the ex ante and ex post domains.
- Development of order-independent waterfall[2] graphics – The waterfall methodology can produce complete and concise visuals to efficiently convey ex ante and ex post savings and discrepancies for all audiences.

The IESR guidelines were developed in a joint effort between the California Public Utilities Commission (CPUC), the Investor-Owned Utilities (IOUs), and independent evaluators. The ESPI database has been developed between the CPUC and evaluators, with input from the IOUs. The order-independent waterfall methodology has been spearheaded by the IOUs with feedback from the CPUC and evaluators. Together, these projects represent a broad collaboration between regulatory, utility and evaluation stakeholders. Below we describe key aspects of each project, with references to more in-depth resources that are publicly available. We also describe the California Energy Data and Reporting System (CEDARS), which is an ongoing collaborative project to improve ex ante data. Finally, we propose a '4-pager' summary format to distill the evaluation story for high level decision makers.

[1] California's Draft Distributed Energy Resources Action Plan defines DERs as *"distribution-connected distributed generation resources, energy efficiency, energy storage, electric vehicles, and demand response technologies."*
[2] Waterfall graphics are bar charts in which progressing stepwise adjustments link an initial quantity to a final quantity. In this paper, waterfall graphics will generally link ex ante gross savings to and ex post net savings.

Impact Evaluation Standard Reporting (IESR)

Energy efficiency savings are counted and cataloged in many ways. Savings are assessed for kWh, kW and Therms on both gross and net bases, within first year and lifecycle time periods, and within ex ante and ex post domains. In California, EE goals and metrics have expanded and evolved to encompass many of these arenas.[3]

With many distinct objectives, all measured with a particular ruler, it is vital that impact evaluations report comprehensive results. Further, because these goals and metrics are subject to change – for instance PA's savings goals are set to shift from gross to net in 2018 – it is important that impact evaluations report results that are comparable from cycle-to-cycle. These ambitions are complicated by the wide variability among programs, and the fact that multiple firms, with different reporting styles and methods, conduct the impact evaluations.

With these issues in mind, the California group worked to establish standardized reporting templates, now used in every EE impact evaluation, to achieve the following basic objectives (CPUC 2015):

1. Comprehensive evaluation results are documented
2. Ex ante vs. ex post savings are comparable
3. Readers can easily access and identify important results
4. Results from different impact evaluations are comparable

To achieve these goals, each report contains standard appendices that detail gross and net savings[4] by measure groups, incidence of claimed and evaluated early retirement,[5] and recommendations. Below, we give examples of the IESR tables, taken directly from the 2014 Nonresidential Downstream Lighting Impact Evaluation (Itron 2014), and discuss important features.

Table 1 shows the first IESR table, which covers gross lifecycle electricity savings. In this, and the following tables, rows that are discussed specifically in the text are highlighted.

Table 1. Lifecycle gross MWh

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	CFL	5,959	5,873	0.99	28.0%	0.98
PGE	Delamp	42,266	33,089	0.78	50.2%	0.56
PGE	LED	118,791	208,025	1.75	0.0%	1.75
PGE	Lighting Outdoor	236,193	236,193	1.00	100.0%	
PGE	Occupancy	41,874	29,948	0.72	18.5%	0.65
PGE	Other Lighting Indoor	227,834	227,834	1.00	100.0%	
PGE	T5Linear	175,325	157,214	0.90	2.0%	0.89
PGE	**Total**	**848,242**	**898,176**	**1.06**	**58.7%**	**1.14**

[3] Currently PA's savings goals are ex ante, first year, gross. The shareholder incentive for the same EE programs is determined in part through ex post, lifecycle, net and in part through ex ante, lifecycle, net savings. The latter are the input into cost effectiveness metrics as well. Targets have also been established for portfolio average effective useful life (EUL). In addition, savings depend on a determination of early retirement (ER) or replace-on-burnout (ROB) status and the associated baselines.

[4] In California gross savings are treated as all of the savings delivered through an EE program. Net savings are generally gross savings minus savings from free ridership, i.e. program savings minus the portion from participants who would have undertaken the EE action in the absence of the program.

[5] In early retirement, functional equipment is replaced and an initial baseline is assigned as pre-existing conditions.

The first two columns give the PA[6] and the "Standard Report Group" (SRG). The SRGs are determined by the evaluator and, when appropriate, allow results from similar measures to be aggregated in order to keep the IESR tables manageable and relevant for readers. The next three columns give ex ante and ex post gross savings, along with the Gross Realization Rate (GRR = Ex Post Gross/Ex Ante Gross).

To understand the last two columns ('% Ex-Ante Gross Pass Through' and 'Eval GRR') and their utility, one must understand passed through savings. Simply put, passed through savings have not been evaluated and therefore ex post savings are equal to ex ante. Entire programs or SRGs may be passed through, or part of a program or SRG may be passed through. Accounting for passed through savings, and documenting the associated impact on realization rates, is a key feature of IESR. The last column of Table 1 ('Eval GRR') gives the GRR for only the portion of savings that is evaluated.

Consider the 'Delamp' SRG in Table 1, which covers delamping measures. The GRR is 0.78, meaning that 78% of the ex ante savings materialized in ex post. However, the next column shows that 50% of the ex ante savings were not evaluated and were therefore passed through to ex post with no adjustment. When isolating the evaluated savings, the Delamp SRG does not perform as well, with an 'Eval GRR' of only 0.56. For a regulator or PA considering the future of the delamping measures, a different decision may be justified when considering an Eval GRR that is significantly different than the total GRR due to the effect of passed through savings.

In contrast to the delamping measures, the next two rows of Table 1 show that the evaluation covered the entire 'LED' SRG while passing through the entire 'Lighting Outdoor' SRG. By definition, GRR = Eval GRR when all measures in a SRG are evaluated. Similarly, GRR = 1.0 when all savings in a SRG are passed through. Finally, the total savings and associated realization rates are given in the last row. Totals show that nearly 59% of savings were passed through, leading to a GRR of 1.06 and Eval GRR of 1.14 for the PG&E savings assigned to this impact evaluation.

Net-to-Gross (NTG) values and net savings are also essential metrics reported in impact evaluations. Table 2 shows the next IESR template. Analogous to Table 1, after the PA and SRG columns, the next three entries give ex ante and ex post net savings and Net Realization Rates (NRR).

Table 2. Lifecycle net MWh

PA	Standard Report Group	Ex-Ante Net	Ex-Post Net	NRR	% Ex-Ante Net Pass Through	Ex-Ante NTG	Ex-Post NTG	Eval Ex-Ante NTG	Eval Ex-Post NTG
PGE	CFL	4,311	3,863	0.90	27.5%	0.72	0.66	0.73	0.63
PGE	Delamp	31,466	24,264	0.77	0.0%	0.74	0.73	0.74	0.73
PGE	LED	88,036	118,108	1.34	0.0%	0.74	0.57	0.74	0.57
PGE	Lighting Outdoor	157,960	157,960	1.00	100.0%	0.67	0.67		
PGE	Occupancy	25,987	18,057	0.69	20.8%	0.62	0.60	0.60	0.57
PGE	Other Lighting Indoor	169,072	169,072	1.00	100.0%	0.74	0.74		
PGE	T5Linear	136,713	94,460	0.69	0.0%	0.78	0.60	0.78	0.60
PGE	**Total**	**613,544**	**585,784**	**0.95**	**54.4%**	**0.72**	**0.65**	**0.75**	**0.59**

As with gross savings, net savings may also have components that are passed through. In particular, ex post NTG may be determined (and ex ante NTG passed through) for none, part, or all of the savings associated with a SRG.

Returning to Table 2, the Column labeled "% Ex Ante Net Pass Through" gives the percentage of ex ante net savings for which the ex ante NTG ratio is passed through. The next four columns give the ex ante and ex post NTG, along with the ex ante and ex post NTG ratios for only the portion of savings for which NTG has been evaluated. Assessing the PG&E totals shows that the ex ante and ex post NTG ratios

[6] In the report, results are given also for the other California electric IOUs along with rolled-up statewide totals.

appear fairly well-aligned at 0.72 and 0.65, respectively. However, the discrepancy between Eval ex ante NTG (0.75) and Eval ex post NTG (0.59) is much greater.

Study of both Table 1 and Table 2 reveal a fundamental characteristic of passed through savings: They act to weigh the GRR, NRR and NTG realization rates toward 1.0. For this reason, excluding the passed through savings often better conveys the true implications of evaluation results. Put another way, the greater the fraction of passed through savings, the higher the risk that ex ante and ex post savings will appear artificially aligned. Tables analogous to those above are generated for first year savings for a total of four tables devoted to electricity savings. These four tables are repeated for peak load (MW) and natural gas (Therms) savings for a total of 12 tables.

Another fundamental set of information is needed for a complete picture of savings and results: effective useful life (EUL) findings along with ex ante and ex post information on early retirement. Table 3 shows the IESR approach in which per unit EUL and ex post savings are given, along with the percentage of measures that were claimed (ex ante) and found (ex post) to have occurred on an early retirement (ER) basis.

Table 3. Per unit gross MWh savings and early retirement rates

PA	Standard Report Group	Pass Through	% ER Ex-Ante	% ER Ex-Post	Average EUL (yr)	Ex-Post Lifecycle	Ex-Post First Year	Ex-Post Annualized
PGE	CFL	0	0.0%		6.6	385.7	86.5	86.5
PGE	Delamp	0	0.0%	83.7%	6.8	1,090.4	196.5	175.3
PGE	LED	0	0.0%		10.0	1,081.3	124.2	124.2
PGE	Occupancy	0	0.0%		8.0	861.2	107.7	107.7
PGE	T5Linear	0	0.0%	42.0%	15.0	7,413.9	587.9	494.3

To understand the features and utility of Table 3, consider the 'T5Linear' SRG. The '% ER Ex-Ante' and '% ER Ex-Post' columns show that all of PG&E's T5Linear measures were claimed as replace-on-burnout (ROB), while the evaluation found that 42% of those measures replaced functional equipment qualifying as early retirement. The next column shows the EUL for T5 measures is 15 years. The next two columns give the per-unit ex post lifecycle and first year savings. The last column gives annualized savings, which are equal to the lifecycle savings divided by the EUL. For measures that are 0% ER (100% ROB), the first year and annualized savings will be equal. In contrast, as the percentage of ER increases, the first year, ex post and annualized savings will reflect a higher fraction of existing conditions baseline for the remaining useful life (RUL) of the measure.

The dual baseline[7] nature of early retirement savings yields a more complex relationship between savings and realization rates. In cases for which an evaluation finds different early retirement rates, and/or makes ex post baseline adjustments, first year and lifecycle GRRs (and NRRs) may be significantly different. For the T5 measures discussed above, the difference between ex ante and ex post early retirement rates leads to substantially different first year (1.06) and lifecycle (0.89) GRRs. Table 3 attempts to give some of the most important information around EUL and ER and the impact on savings without becoming overly byzantine.

Finally, the IESR guidelines (CPUC 2015) provide a template for evaluation recommendations. For each recommendation, the template requires a summary of the associated key findings and data, a reference for where additional information can be found in the report/appendices, the target of the recommendation, and specification of any database or workpapers for which the evaluators are suggesting changes. For more information on motivation behind IESR, the specific guidelines, and example templates, we refer the reader to the official IESR guidelines (CPUC 2015).

[7] Dual baselines occur in cases of early retirement. The first baseline period accounts for the 'remaining useful life' of the pre-existing equipment. The second baseline period is defined as code or industry standard practice.

The Energy Savings and Performance Incentive (ESPI) Database

The IESR tables catalog savings, realization rates, and EUL/ER information for each impact evaluation. However, for stakeholders with needs for either higher level or more granular information, a different reporting structure is required. For instance, EE stakeholders may need to know:

- Portfolio-level savings and realization rates
- Program-level savings and realization rates
- Individual measure-level savings and realization rates
- The performance of EE within specific sectors, (i.e. residential or commercial), technology families (i.e. lighting or HVAC), or delivery channels (i.e. upstream or downstream)

These and many other questions can now be answered in California through a claim-level database, the Energy Savings and Performance Incentive (ESPI) database.

Giving PAs the ability to readily verify proper accounting for all savings claims, which facilitates validation of shareholder incentive payments, was the initial driver for creation of the ESPI database. Over time, the primary goal of the ESPI database has evolved to provide a straightforward, comprehensive single source reference for California EE program savings.

Creating the ESPI Database requires compiling all ex ante savings claims reported by each PA, cataloging all adjustments made by the CPUC,[8] and appending ex post results from the impact evaluations. Important classifying information is also included, such as sector, channel, measure code etc., which allows slicing and aggregating data in many dimensions via custom queries. These various data have traditionally been housed in disparate locations and in varying forms, which made even standard comparisons and verifications nearly impossible.

By compiling these different savings values and supplemental information into one source at the same level of segmentation, the ESPI database allows users to quickly extract desired information with the confidence that the data is complete and comparable. The ESPI database also provides the platform for the creation of the IESR appendices (described above), all data summaries and graphics for the ESPI Performance Statement (CPUC 2016), and many additional preset summaries.

An example of custom query results is given in Table 4. This table shows ex ante and ex post savings and NTG values, along with realization rates at the sector level for PG&E.[9] This information is not available through the impact evaluations, but can be readily ascertained with the ESPI database.

Table 4. 2014 PG&E first year savings (GWh) and realization rates at the sector-level

Sector	Ex Ante Gross	Ex Post Gross	GRR	Fraction Ex Ante Evaluated	Eval GRR	ExAnte Net	ExPost Net	NRR	Ex ante NTG	Ex post NTG
Com	222.6	192.5	0.86	0.62	0.78	142.7	110.8	0.78	0.64	0.58
IALC	190.3	134.8	0.71	0.93	0.69	131.3	72.1	0.55	0.69	0.53
Res	276.8	322.9	1.17	0.76	1.22	209.4	224.9	1.07	0.76	0.70
GP	110.2	97.5	0.88	0.64	0.82	75.7	58.7	0.78	0.69	0.60
Total:	**799.9**	**747.7**	**0.93**	**0.75**	**0.91**	**559.1**	**466.5**	**0.83**	**0.70**	**0.62**

[8] The PA reported ex ante values, not included in an ex post impact evaluation, undergo a review by ED staff and their contractors for accuracy. Any errors or issues are adjusted for the purposes of the savings incentive portion of the shareholder incentive payment.

[9] Commercial, Industrial Agricultural and Large Commercial, Residential, and Government Partnerships.

Overall, the ESPI database provides transparency and a comprehensive source of savings information for PAs and all EE stakeholders. A database is created for each California IOU in Microsoft Access. These are publicly available and can be downloaded, along with a corresponding data dictionary (CPUC 2016).

Developing Impact Parameters and Waterfall Graphics

The IESR tables and ESPI database resources provide for comprehensive, consistent and in-depth ex ante and ex post data. However, neither resource yields insight into how savings were achieved, or the reasons for discrepancies between ex ante and ex post. This information is vital for a PA to make optimal decisions, for stakeholders to take informed positions, and for engineering updates to ex ante calculations. Therefore, an impact evaluation is most actionable when a clear and quantitative delineation of the reasons behind ex ante/ex post discrepancies is given.

When this type of breakdown is available, waterfall graphics can provide efficient visuals that show both savings and adjustments. A waterfall figure can connect a straightforward path from ex ante and ex post, as well from gross to net savings. However, care must be taken to avoid distortions as each step builds upon the last. A current whitepaper gives a detailed summary of how to develop quantitative impact parameters and use them to produce accurate, waterfall graphics with *order-independent* steps (Scheer 2017). Here we give a brief synopsis and describe new developments and resources available to assist in making waterfall graphics.

In any impact evaluation, an evaluator must determine how to assess ex post gross savings. For many programs that determine ex ante savings claims via deemed[10] estimates, the impact evaluation can investigate the multiplicative parameters that led to ex ante estimates. Consider a deemed lighting program. Common engineering parameters to figure both ex ante and ex post savings include average Hours of Use (HOU), Delta Watts (ΔWatts), and In Service Rate (ISR). With these parameters one determines ex ante gross kWh savings with a simple equation:

$$Ex\ Ante\ Gross\ kWh\ Savings = Quantity \cdot HOU_{XA} \cdot \Delta Watts_{XA} \cdot ISR_{XA} \qquad (1)$$

Where Quantity is the number of lamps incentivized and XA designates ex ante. Analogously for ex post,

$$Ex\ Post\ Gross\ kWh\ Savings = Quantity \cdot HOU_{XP} \cdot \Delta Watts_{XP} \cdot ISR_{XP} \qquad (2)$$

When ex post savings are determined, the GRR can be determined via a simple ratio of ex post to ex ante savings:

$$GRR_{kWh} = \frac{Ex\ Post\ Gross\ kWh\ Savings}{Ex\ Ante\ Gross\ kWh\ Savings} \qquad (3)$$

Equivalently, the GRR can be determined by development of dimensionless impact parameters, which are ratios of the ex post to ex ante engineering parameters:

$$GRR_{kWh} = \frac{HOU_{XP}}{HOU_{XA}} \cdot \frac{\Delta Watts_{XP}}{\Delta Watts_{XA}} \cdot \frac{ISR_{XP}}{ISR_{XA}} \qquad (4)$$

Each ratio on the right hand side of Eq. 4 is a multiplicative impact parameter that feeds directly into the GRR and can be used to quantitatively illustrate the reasons for ex ante and ex post

[10] "Deemed" savings refer to engineering estimates for the *average* savings that would be expected for a particular EE measure.

discrepancies. In the figures that follow, the dimensionless impact parameters will be listed without subscripts. Consider the following example impact evaluation results for a lighting program (Tables 5 and 6):

Table 5. Example Multiplicative Impact Parameters

	Hours of Use (HOU)	ΔWatts	In Service Rate (ISR)
Ex Ante	3.0	42	0.98
Ex Post	2.1	48	0.62
Impact Parameter	0.70	1.14	0.63

The dimensionless impact parameters of Table 5 are utilized in Table 6, along with ex ante and ex post NTG values, to calculate savings and realization rates.

Table 6. Example savings and adjustments

		Impact Parameters									
Ex Ante Gross (kWh)	Ex Ante Net (kWh)	HOU		ΔWatts		ISR		GRR	Ex Post Gross (kWh)	NTG_{XP}	Ex Post Net (kWh)
100	80	0.70	x	1.14	x	0.63	=	0.5	50	0.6	30

With these data and the order-independence framework detailed comprehensively elsewhere (Scheer 2017), the Fig. 1 waterfall graph can be constructed, which gives a concise and accurate synopsis of gross savings and adjustments.

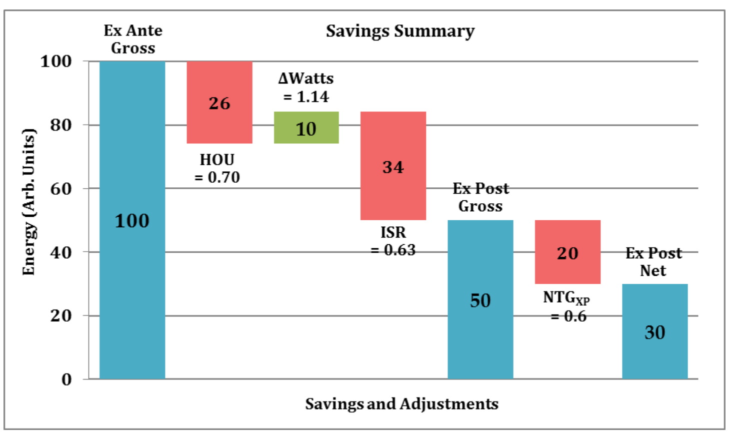

Figure 1. An order-independent Gross waterfall graphic displaying the savings and adjustments given in Table 5.

The left side of this graph gives gross savings and a parameter-level breakdown of the associated ex ante/ex post discrepancies. The ex post NTG is then applied to ex post gross savings to yield ex post net.

While Fig. 1 provides comprehensive information for stakeholders interested exclusively in gross savings, it falls short for those interested in the net domain. In work published elsewhere (Scheer 2017), this group has developed a conversion procedure from the gross to net domains, which hinges on equations 5 and 6.

$$Net_{XP} = Net_{XA} \cdot GRR \cdot NTG_{RR} \qquad (5)$$

where NTG_{RR} is identified as the net to gross realization rate.

$$NTG_{RR} = \frac{NTG_{XP}}{NTG_{XA}} \qquad (6)$$

The NTG_{RR} quantifies the misalignment between ex post NTG and ex ante NTG. We are now ready to construct an order-independent waterfall graphic with the Table 6 data that is more useful for stakeholders interested in net savings (Fig. 2).

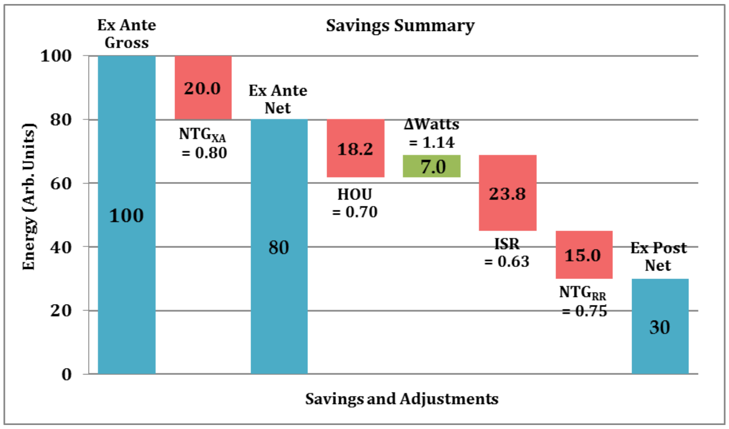

Figure 2. An order-independent Net waterfall graphic displaying the savings and adjustments given in Table 5.

In Fig. 2, the gross savings adjustments of Fig. 1 have been recast in the net domain. However, the total adjustments due to free ridership[11] and gross savings discrepancies differ between the two plots. In Fig. 1, the NTG adjustment is ex post NTG applied to ex post gross savings, which yields a step of -20. In contrast, in the Net waterfall of Fig. 2, totaling the steps due to free ridership gives an adjustment of -35, resulting from the sum of the ex ante NTG and NTG_{RR} adjustments. This apparent paradox stems from the ex post gross and ex ante net 'stopping points' in Figs. 1 and 2 respectively.

While some stakeholders may need results specific to gross or net savings, forcing either of these domains skews the relationship between gross savings adjustments and free ridership. Therefore, the Gross and Net waterfalls can be considered only semi order-independent. The Gross waterfall forces a stopping point of Ex Post Gross savings, which forces NTG_{XP} as the last step, and therefore is not completely order independent. A similar situation occurs in the Net waterfall with the first step being NTG_{XA}. Eliminating these categorical stopping points yields a Hybrid waterfall in which every adjustment between ex ante gross and ex post net is made in the same domain (Fig. 3).

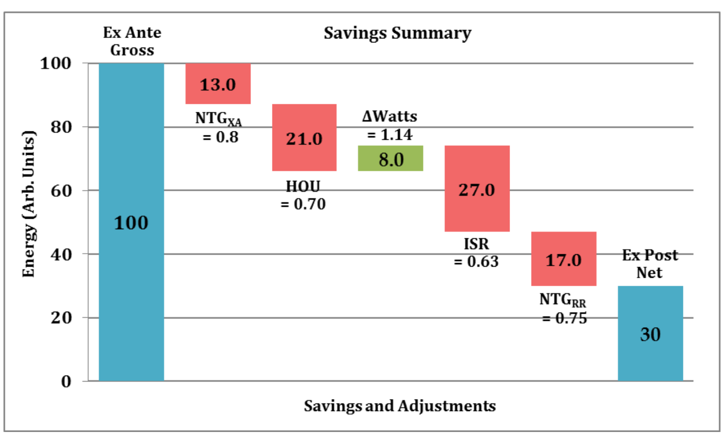

Figure 3. An order-independent Hybrid waterfall graphic displaying the savings and adjustments given in Table 5.

[11] In this paper we assume that NTG reflects only free ridership unless otherwise noted.

Instead of using multiplicative parameters, some impact evaluations may determine ex post savings via additive adjustments to ex ante estimates. For instance, a custom impact evaluation that assesses savings from comprehensive projects on a collection of distinct and non-dependent systems may isolate savings and adjustments for each system. In such a case, creating the Gross waterfall is simple because no calculations are needed to ensure order-independence. However, the Net and Hybrid waterfalls still require some computation. More details are provided in the whitepaper (Scheer, 2017).

To facilitate creation of waterfall graphics, PG&E has partnered with EMI Consulting to create an online tool.[12] A user needs only provide the ex ante gross savings, multiplicative or additive impact parameters, and ex ante and ex post NTG information, and the tool will compute downloadable waterfall graphics with customizable labels and color schemes, along with the corresponding tables of order-independent adjustments. For more advanced users, the R package script to complete computations is also available.[13]

Figure 4 shows Gross, Net, and Hybrid waterfall graphics for PG&E LED Reflector measures taken from the 2015 Upstream Lighting Impact Evaluation (DNV GL 2017). The figures have been slightly modified[14] here for simplicity.

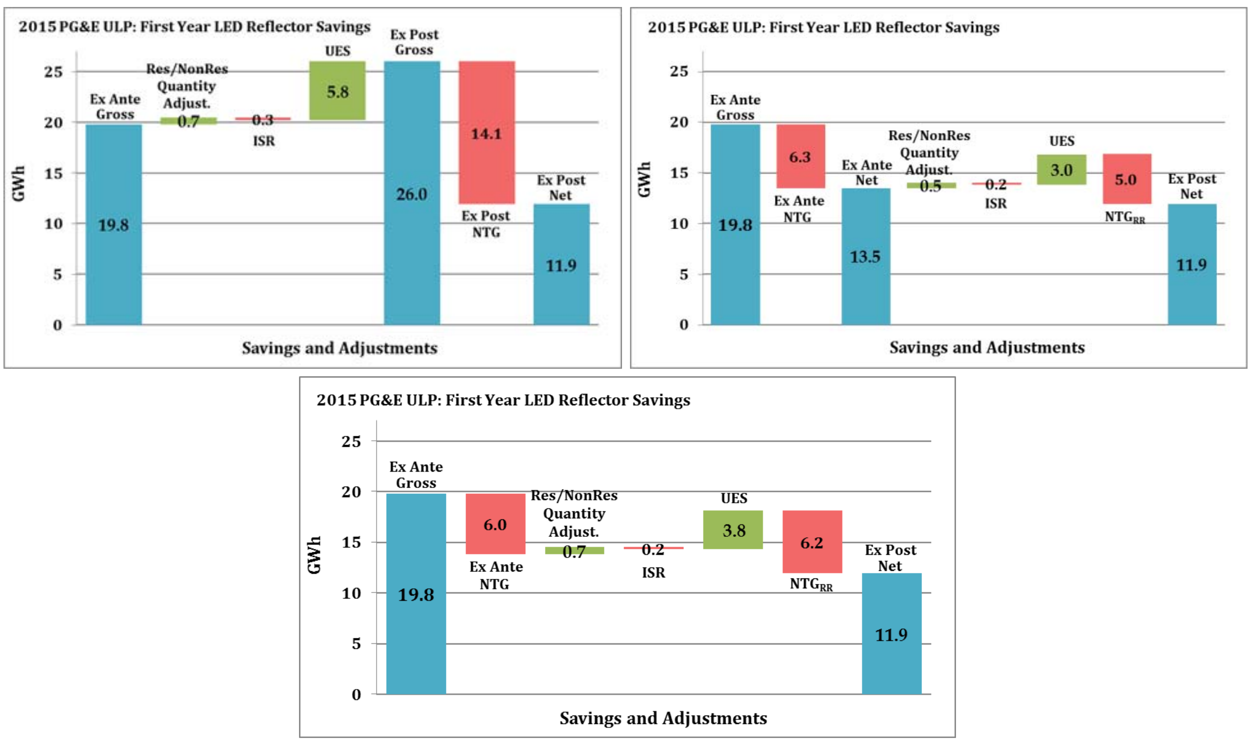

Figure 4. order-independent Gross (top left), Net (top right), and Hybrid (bottom) waterfall graphics displaying first year savings and adjustments for PG&E's 2015 LED reflector measures.

These waterfalls provide a concise and quantitatively accurate visual story of the full impact evaluation results for these measures. The (UES) adjustment, which consists of hours of use and delta watts factors, substantially increases gross and net savings. However, both ex ante NTG and lower ex post NTG drive

[12] https://emijess.shinyapps.io/evalwaterfallr_shiny/
[13] https://github.com/EMIjess/evalwaterfallr
[14] Corresponding waterfall graphics in the report show two distinct ex post NTG adjustments, one devoted to free ridership, and another reflective of a different mix of technologies represented by in store lamp purchases and in-home socket saturation. These adjustments are combined here.

net savings downward. Slight adjustments are needed to account for misalignment between quantities of lamps sold for residential and non-residential applications and for in-service rates.

In summary, order-independent waterfall graphics of gross, net, and hybrid savings concisely convey reported savings, evaluated results, and the reasons for ex ante/ex post misalignment in formats that satisfy multiple and diverse audiences. These waterfall graphics can be produced for both multiplicative impact parameter adjustments, which can often be developed for deemed savings, and additive adjustments, which may be more common in custom programs. To facilitate the calculations and produce order-independent Gross, Net and Hybrid waterfalls for either multiplicative or additive impact parameters, we have made an easy-to-use online tool publicly available.

The California Energy Data and Reporting System (CEDARS)

Thus far we have discussed steps California has taken to enhance impact evaluation reporting and the data sources available to all EE stakeholders. But it is worth noting that an evaluation or database can only be as good as the data itself allows. Understanding this, the improvements we detail above are rooted earlier in the program oversight process. The same group of collaborators - CPUC, IOUs and consultants - has worked over numerous EE program cycles dating to 2006 to standardize IOU savings claims. These ex ante savings provide the fundamental data for the evaluation studies, serving as the foundation for sampling plans, verification tasks, formation of standard report groups, and more.

During the 2016 program year, the outcome of this incremental process took definitive form in a custom-coded online reporting platform known as the California Energy Data and Reporting System, or CEDARS. This system solved previous standardization breaches with thousands of rows of quality control and validation code to machine-enforce the reporting specification. The CEDARS platform rejects erroneous values that do not adhere to the specification and compliance rules, and gives "warnings" to the program administrator for values that the systems interprets as potentially incorrect.[15] When the data tables are fully accepted without errors by the system, the PA manager verifies savings and costs, clicks "confirm," and the data automatically moves to the integrated cost effectiveness tool for final processing and verification by the CPUC.

Adoption of a change management protocol that ensures reliability between multiple ex ante data resources (the Database for Energy Efficient Resources,[16] work paper data and ex ante claims) as well as the enforcement of the statewide specification in CEDARS, ensures the quality of data feeding into program evaluations. The CEDARS platform also allows for considerably shorter processing time and at lowers costs. The future vision for CEDARS includes data integration from all program stages—ex ante work papers, to claims, to final evaluation results—to form a fully-relational data system capable of generating outputs to inform robust statewide planning.

The '4-Pager': The Executive Summary of the Executive Summary

While waterfall graphics give a concise visual and parameter-level breakdown of savings and adjustments, an even higher-level summary may be useful for many stakeholders. Here we propose a '4-pager' template (Figure 5) to tell the impact evaluation story for layman audiences and give more technical readers a useful briefing. The 4-pager is not meant to take the place of executive summaries.

[15] For example, if dual baseline is reported, then "measure_application_type" *should* be early retirement; however, there might be a justification found in a work paper that allows for this exception so CEDARS issues a warning but accepts the value.
[16] http://www.deeresources.com/

Yet an executive summary of a technical impact evaluation can still be somewhat lengthy, use complex terminology, and cover complicated concepts, thus presenting a barrier of entry to the general reader.

As the EE community moves toward broader audiences with expectations for contemporary presentation of information, attractive graphic representation and visualizations, can help reach a broader readership, including policy decision makers. In our 4-pager each page has a standalone purpose: 1. Overview, 2. Approach, 3. Findings, 4. Conclusions.

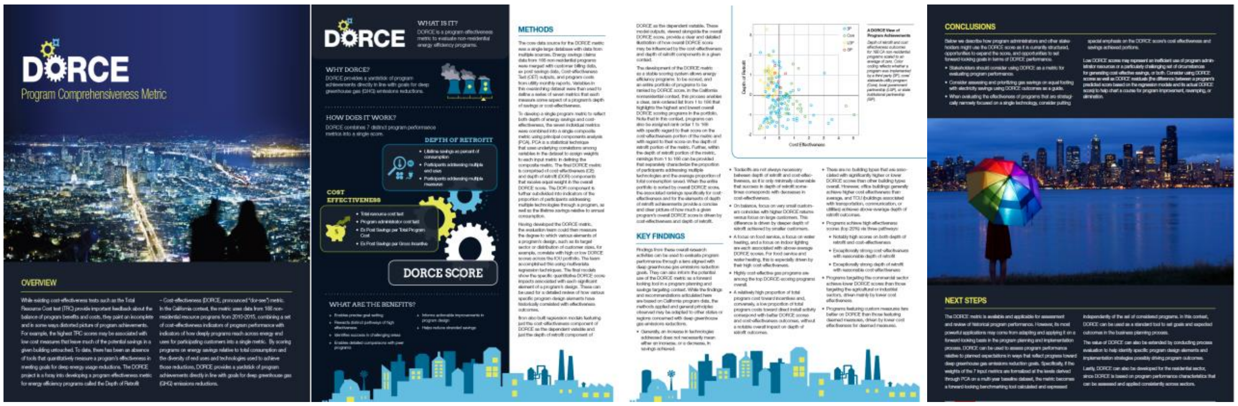

Figure 5. An example of the '4-pager' summary template.

Each page makes use of visualizations, info-graphics, and condenses information into short form presentation. The "Overview" page is no more than a few paragraphs and one or two graphics. This section is intended give a general reader the necessary information to understand the research at a high level. This page highlights the problem statement, area of study, and general purpose for the impact evaluation.

The "Approach" page covers the primary aspects of how the study was conducted. Ordered lists with steps, flow charts, and diagrams are useful graphics in this section. It should illuminate the steps of how the population and sampling criteria were determined, how the data was developed, and how the analyses were conducted.

The "Findings" page highlights the key outcomes of the research. This section should have no more than a few bulleted sentences and a few graphics. In the case of a standard impact evaluation, this would be a key location for the waterfall graphics to be located.

The "Conclusions" page is the impact evaluation team's opportunity to frame the work in the broader scheme. It provides the talking points and synthesized key points for the general reader. It can highlight how the work leads to future research, the questions that have been answered, or support the "Findings" section with discussion.

These four sections together create a story for the reader that provides a brief, but thorough synopsis. The 4-pager is intended to be a standalone document, from which a general reader can garner the pertinent information, while also encouraging a more technical stakeholder to delve into the details of the full report. Each page is not intended to be a full journal style document, but rather a visually stunning and eye-capturing presentation. Four presentation style pages are short enough to capture nearly any audience, but long enough to give insight into the main aspects of a research project.

Conclusion

Here we have described a multipronged effort that California has undertaken to enhance impact evaluation reporting and to provide all stakeholders with high quality, consistent, and comprehensive data that covers the energy efficiency programs. As the energy landscape evolves in the coming years, these steps will help ensure that EE is a reliable and understood resource alongside traditional generation and other distributed resources. In the future, states may be held to national EE goals and mandates, which will make the need for complete and consistent reporting paramount. The methods and resources described here can be used by other states and jurisdictions to improve completeness and transparency.

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