White Paper: Cost Analysis Guidance for the California Statewide Deemed Energy Efficiency Measures

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DRAFT

INTRODUCTION

Purpose

This white paper categorizes the current practices for estimating measure costs of the statewide deemed energy efficiency measures approved for the California portfolios. This document proposes a framework to help measure developers determine the most appropriate data sources and methods to estimate measure costs for measures proposed in the future.[1] Ultimately, this guidance is intended to:

- Facilitate the consistency of data sources and methods to estimate measure costs for measures with similar attributes (i.e., same end use, technology group, supply chain, etc.).
- Provide greater transparency into how measure costs are estimated.
- Provide measure developers with trade-offs associated with each method to ensure the most cost-efficient data and approach is adopted in arriving at the most accurate result possible.

The need for cost-effective energy efficiency programs continues to grow in California as the state strives for meeting statewide energy and carbon reduction targets. The California energy efficiency deemed measure portfolios have undergone dramatic changes over the last few years, which are not yet complete. The decreasing savings from lighting, the shifting peak periods from added solar generation, and the increased reliance on third-party (3P) programs, for example, will result in significant changes to the portfolios but will also offer great opportunities.

The California Technical Forum (Cal TF) led three important foundational steps to support this transition.

- The Cal TF consolidated investor-owned utility (IOU)-specific workpapers and the publicly-owned utility (POU) technical reference manual (TRM) into a single set of statewide deemed measures. This has simplified the deemed pathway.
- The Cal TF has developed the California electronic TRM (eTRM). As a centralized repository, the eTRM offers all statewide deemed measures (all values and associated documentation) in a transparent, structured, and accessible format.
- The Cal TF has coordinated the development of a new measure development and review process that offers a streamlined path for new measures from the private sector (3Ps) into the portfolios.

As the eTRM transitions into the data source of record for statewide measures and the new measure proposal process ramps up, Cal TF is expecting an influx of new measures proposals from IOUs, POUs, and 3P measure developers. Maintaining the level of documentation quality for the California deemed measures remains a primary goal that must be balanced with the need to increase market adoption rates and manage costs. As a result, there is a need to develop a framework for estimating measure costs to guide the measure developers to produce a quality deemed measure in a cost and time efficient manner.

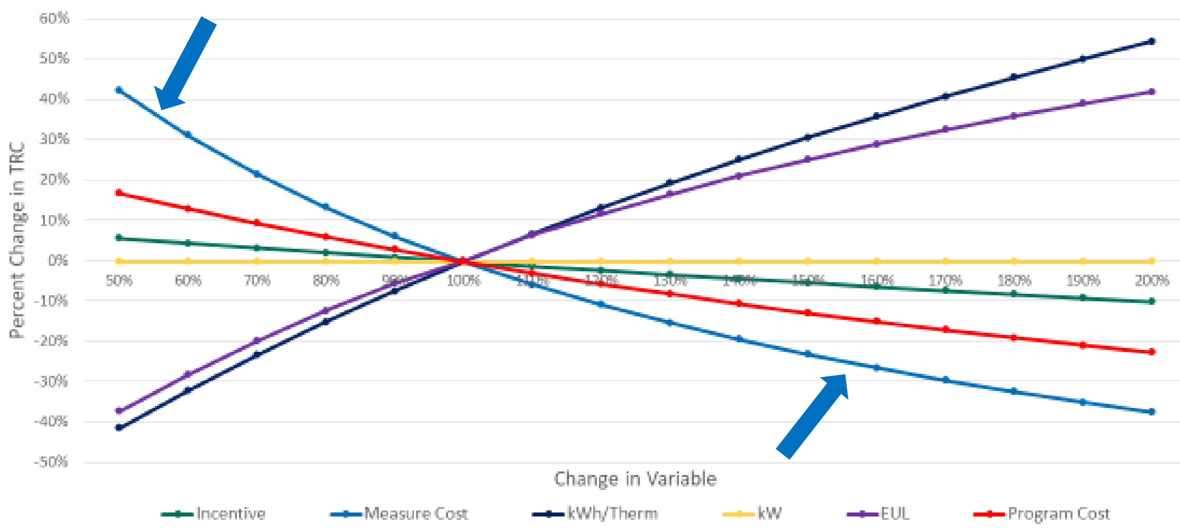
[1] Throughout this paper "measure costs" is used generically but refers to all cost elements needed to estimate the prices paid for both the high efficiency (measure case) technologies and their existing equipment or standard efficiency counterparts. Whether the incremental measure cost or full measure cost is used to evaluate measure cost effectiveness depends upon the measure application type.

Without established guidelines for statewide measures, diverging from best practices may become too easy since reviews are performed one measure at a time. This framework ensures a reasonable standard of estimating measure costs that will satisfy the Cal TF goals of accuracy, transparency, cost efficiency, and consistency.

Background

Cost is a Key Driver of Measure Cost-effectiveness

For context, it is important to understand that measure cost is among the top three drivers of measure cost-effectiveness.[2] The relative effect of various terms of measure cost effectiveness (represented by the total resource cost value, TRC) is indicated in an analysis completed by the IOUs in 2019. As shown in the figure below, the TRC value is most sensitive to measure cost, savings, and measure life.



Source: "Cost-Effectiveness Training" (1/7/2019)

Regulatory Underpinnings and Measure Cost Requirements

The requirements for cost analysis are rooted in a handful of decisions and guidance documents set forth by the California Public Utilities Commission (CPUC). Importantly, the *California Standard Practice Manual* establishes requirements for project and measure costs as required inputs for cost effectiveness tests.[3] While the range of costs that must be quantified depends upon the test to be computed, the costs for

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[2] The net-to-gross ratio has a significant effect but was not included in this test.

[3] California Public Utilities Commission (CPUC). 2001. *California Standard Practice Manual. Economic Analysis of Demand-Side Programs and Projects.* October.

the TRC, the primary indicator of cost effectiveness for IOU energy efficiency programs), include "all equipment costs, installation, operations and maintenance, cost of removal (less salvage value), and administration costs" regardless of who pays for them. (p 18) The Standard Practice Manual does not stipulate cost data sources or methods for analyzing cost data to derive final measure cost values to be utilized in the TRC calculation.

While the Standard Practice Manual does not explicitly stipulate the type or source of data to calculate measure cost, the CPUC has provided the "guard rails" that Database for Energy Efficient Resources (DEER) assumptions, methods, and data shall be utilized for all non-DEER measures. Specifically, D.12-05-015 instructed the IOUs to use DEER values as a "starting point" and when appropriate and that the utilities cannot replace DEER assumptions and values without approval from CPUC Staff.[4] The *Energy Efficiency Policy Manual* (version 6) further states that if "DEER values and methods are not available, new values may be proposed for CPUC Staff review and approval";[5] the Policy Manual further states that program administrators (PAs) "must utilize the latest information available, including the CPUC's most recently available evaluation results, when updating or developing new workpapers … All ex ante values are to be updated or developed in consideration of the latest information available, including Unit Energy Savings (UES), Effective Useful Life (EUL), Installation Rate (IR), NTG and Cost."[6] This direction was rooted in the fact that the DEER measures, which are created, updated, and under the purview of the CPUC ED ex ante review team include high-impact measures (HIMs) and others that account for the largest portion of portfolio savings.

Most recently in May 2020 CPUC Staff have acknowledged that cost values in DEER are becoming outdated and thus should <u>not</u> be used for future measure updates and for new measures.[7] This sentiment has not been codified into formal regulatory direction.

D.92-02-075 (1992) articulated the CPUC requirement that PAs should analyze the cost effectiveness of demand-side management programs in a manner consistent with the Standard Practice Manual. D.92-02-075 also established the TRC test as the primary test for determining cost effectiveness and that portfolios were also required to meet the PAC test.

[4] California Public Utilities Commission (CPUC). 2012. *Decision 12-05-015 in the Order Instituting Rulemaking to Examine the Commission's Post-2008 Energy Efficiency Policies, Programs, Evaluation, Measurement, and Verification, and Related Issues (R.09-11-014).* Issued May 18. Pp. 331, 338.

[5] California Public Utilities Commission (CPUC), Energy Division. 2020. *Energy Efficiency Policy Manual Version 6.* April. Sections IV.2.

The *Energy Efficiency Policy Manual* documents policy rules related to the administration, oversight, and evaluation of the energy efficiency programs funded by California ratepayers. The Policy Manual is not formally adopted by the CPUC, rather serves as a comprehensive but not exhaustive reference for the more significant rules set forth by the CPUC in various decisions and resolutions. (p. 2)

[6] Ibid. Section V.

[7] CPUC & Statewide IOU Workpaper Coordination Meeting Notes. May 26, 2020. P.3.

California Measure Cost Studies

The history of measure cost studies in California dates back to the late 1990s[8] and includes five measure cost update studies, conducted roughly every three to four years. The two most significant and recent studies conducted by CPUC evaluation contractors to update DEER cost values are the measure cost study of the 2010 – 2012 program cycle as part of the CPUC contract Work Order 17 and the 2008 DEER measure cost study.

The *2010-2012 WO017 Ex Ante Measure Cost Study*[9] ("WO017") is a comprehensive study that updated ex ante measure cost estimates of over 100 unique DEER and non-DEER deemed measures. The data collection strategies were based upon an assessment of data sources and methods of all measures included in the study, acknowledging that different data collection strategies are necessary for different measures/measure groups due to supply chain characteristics and other challenges, such as cost, availability, and competitive sensitivity. The study sought to rely heavily on regression-based cost models (such as hedonic analysis) to estimate costs (roughly 75% of the measures) and the resultant estimates were independently validated with market data.[10] If hedonic price models were not used, measure costs were derived from other sources, including a matrix of subcontractors with specific technology or end use expertise. In addition to developing measure cost values, this study sought to standardize measure cost analysis by recommending data sources and analysis methods for technology groups defined for the study.

In contrast to WO017, the scope of the *2008 DEER measure cost update* [11] included only DEER measures. A range of data sources and analytical methods were used to estimate costs; regression-based models were used for nine of the 17 measure categories. If cost models were not used, measure costs were computed as a weighted average, simple average, or a custom method (for motors only).

Prior to the 2008 study, previous DEER updates that included measure costs are the 2004-2005 and the 2001 studies.[12]

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[8] The first of the five studies was published in 1996. See:
XENERGY, Inc. 1996. *1996 Measure Cost Study Final Report.* Prepared for the California Demand-Side Management Advisory Committee.

[9] Itron, Inc. 2014. *2010-2012 WO017 Ex Ante Measure Cost Study Final Report.* Prepared for the California Public Utilities Commission.

[10] Regression analyses are used to statistically identify the relationship between two or more variables. For example, a regression model can be used to determine the relationship between equipment cost and capacity to estimate costs when cost data is not available for certain capacity categories. Hedonic prices models are a type of regression analysis used to determine the relative influence of attributes (capacity, energy performance rating, color, etc.) on an independent variable (price).

[11] Keneipp, F. and M. Yim. (Summit Blue Consulting, LLC). 2008. *2008 DEER Measure Cost Documentation Revision 3.*

[12] Itron, Inc. 2005. *2004-2005 Database for Energy Efficiency Resources (DEER) Update Study - Final Report.* Prepared for Southern California Edison.

Xenergy Inc. 2001. 2001 *DEER Update Study. Final Report.* Prepared for the California Energy Commission. August.

Current Issues and Gaps

While there has been considerable effort to improve the development and review of ex ante values, issues and gaps exist that contribute inconsistencies and lack of rigor of the cost analysis of some deemed measures.

Investment in measure cost development is low relative to its importance. Despite emphasis on the development of ex ante savings values, there has been relatively low investment to develop ex ante measure costs. **"**Even in CA … investment in impacts-related research roughly 100x more than cost research … Current body of knowledge is small and innovations have lagged".[13] Further, even though reliance on ex ante values and the development of technical resource manuals throughout the U.S. has increased, only a small number of TRMs provide ex ante cost values.[14]

Absence of comprehensive measure cost update study. Since the late 1990s, a measure cost update study has been conducted for California about every three to four years; a comprehensive study has not been commissioned since WO017, which analyzed the 2010-2012 portfolio measures (DEER and non-DEER) and was published in 2014. Recently CPUC Staff acknowledged WO017 cost estimated to be outdated. Further, while some measures covered by WO017 remain in the IOU portfolios today, many are not. The PAs are now in the position of developing cost estimates for new measures and updating costs of existing measures on their own. As the analysis presented herein reveals, the current methods to estimate measure costs have significantly diverged from the approaches used for WO017 measure cost updates.

Lack of explicit guidance to PAs for cost development. Aside from the requirements set forth in the Standard Practice Manual and subsequent direction on the cost inputs for the TRC and PAC calculations, the CPUC has not provided explicit direction on how to develop measure costs. This is logical – the role of the CPUC ex ante review team is to review all estimated values, assumptions, and inputs rather than to provide a priori direction. Any internal or informal guidance that might exist among the IOUs is not documented and accessible to all measure developers (utilities or 3Ps).

The legacy utility-specific workpaper system did not support consistency. Prior to 2019 when the first generation of statewide deemed measures were submitted to and approved by the CPUC, IOUs were required to submit workpapers for all deemed (DEER and non-DEER) measures to be implemented within their service area. These legacy IOU-specific measures were developed independently, and measure data were not available in a centralized repository, both factors contribute to inconsistency and inefficiency.
These factors have since been addressed through the development of statewide deemed measures for the California portfolios and the launch of the eTRM as the repository of all deemed measures and associated data. When looking at measures across the entire portfolio, it is easier to recognize trends that could lead to consistency and rigor.

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[13] Ting, M. (Itron, Inc.) 2014. "Energy Efficiency Measure Cost Studies." SEE Action Webinar – EM&V Working Group. September 24.

[14] Ibid.

California deemed measure reviews or updates do not occur on a specific cadence or schedule. Some parameters, such as costs, should be examined on a regular basis to determine if market changes since the last update are significant enough to update values (regardless if they are DEER measures or non-DEER measures). Currently, there is no process established in California to review all measures on a regular schedule to determine if updates are warranted. Rather, measure updates in California are typically triggered by code/baseline changes or the addition or removal of measure offerings; cost is rarely the impetus for review.[15]

Fundamental data collection and data analysis challenges will need to be considered and are key drivers to data collection strategies and analytical methods. Itron has led several comprehensive cost update studies for California and other states and has documented fundamental challenges associated with measure cost development.[16] A few of the most significant challenges include:

- Lack of comprehensive data that is publicly available (see table below).
- Costs must account for diversity of products (and prices) that fall within the measure/measure offering definition.
- Difficulties in developing data to support both baseline and measure definitions.
- Difficulties in isolating incremental cost associated with only the change in energy performance.
- TRC requires lifecycle costs, which must include O&M, disposal, and other parameters that are not well-known and difficult to estimate.

Overcoming these challenges might be even more difficult as IOUs and 3Ps develop new measures and update existing measures for which they must develop measure costs on their own.

Key Data Collection Challenges

Data Source	Pros	Cons
Program invoice data	▪ Actual prices paid for in-program products ▪ Often contain make/model # ▪ Estimates of sales volumes	▪ In-program products only ▪ No installation costs ▪ No baseline information
DI and 3P price lists	▪ Often includes separate installation costs	▪ Small sample sizes ▪ Narrow measure coverage ▪ No sales volumes
Retailers – shelf survey	▪ Rich data on product prices and features	▪ No sales volumes ▪ Time consuming and expensive

[15] LEDs are a notable exception, which exhibited rapid market changes and declining costs. Even cost reviews for LEDs were not on pace with rapid market changes.

[16] Ting, M., M. Rufo, and J. Loper. 2013. "Measure costs – the forgotten child of energy efficiency analysis." ECEEE Summer Study Proceedings. Pp. 2081 – 2091.

Ting, M. (Itron, Inc.) 2014. "Energy Efficiency Measure Cost Studies." SEE Action Webinar – EM&V Working Group. September 24.

Data Source	Pros	Cons
Web-crawlers/lookups	▪ Rich data on product prices and features	▪ No sales volumes ▪ No installation costs
Manufacturer catalogues	▪ Rich data on product prices and features	▪ No sales volumes ▪ No installation costs ▪ MSRP are not actual prices
Market actor interviews	▪ Separate estimates of installation costs can be tied to specific or prototypical system configurations and site conditions	▪ Small sample sizes ▪ Self-reported estimates, not observed data
Construction pricing books	▪ Widely used by contractors ▪ Separate estimates of installation costs	▪ Equipment specs often lack energy performance ▪ Limited applications to incremental cost analysis
Point-of-sale data	▪ Very large samples of actual prices paid ▪ Rich data on product prices and features ▪ Includes sales volume	▪ Limited to mass market measures ▪ Model number masking for low-volume products ▪ Moderately expensive for certain products

Source: Ting, M. (Itron, Inc.) 2014. "Energy Efficiency Measure Cost Studies." SEE Action Webinar – EM&V Working Group. September 24.

CURRENT STATE

This section summarizes current practices with respect to estimating measure costs. The approach Cal TF staff followed to categorize data sources and methods is explained, followed by a summary of results of current practices to estimate material costs and installation costs. This section concludes with a discussion of key findings from the analysis. Cal TF recommendations and proposed guidance for measure developers are provided in the final section of this paper.

Approach

The objectives of this analysis were to categorize cost data sources, data vintage, and analytical methods to develop measure costs. Prior to 2019, all deemed measures in the IOU portfolios were developed by each IOU separately; as a result, the deemed measures lacked consistency. Beginning in mid-2017, Cal TF Staff worked with subcommittees that were focused on each specific end-use. Each subcommittee, which was comprised of a team of IOU and POU staff who lead and develop deemed measure workpapers, as well as stakeholders with end-use specific experience, "consolidated" the utility-specific workpapers into statewide measures.

This "consolidation process" entailed a detailed review and comparison of parameters, inputs, assumptions, and energy/demand and costs analysis methods of all utility-specific workpapers pertaining to the same measure to reach consensus on how to develop one single statewide measure.

To understand current practices, Cal TF Staff leveraged knowledge from the consolidation process and reviewed and catalogued the data sources and methods used to estimate measure costs for 116 statewide deemed measures that have been affirmed by the Cal TF and have been subsequently approved for the portfolios.[17] The analysis of measure costs began in the summer of 2019 and concluded in May 2020.

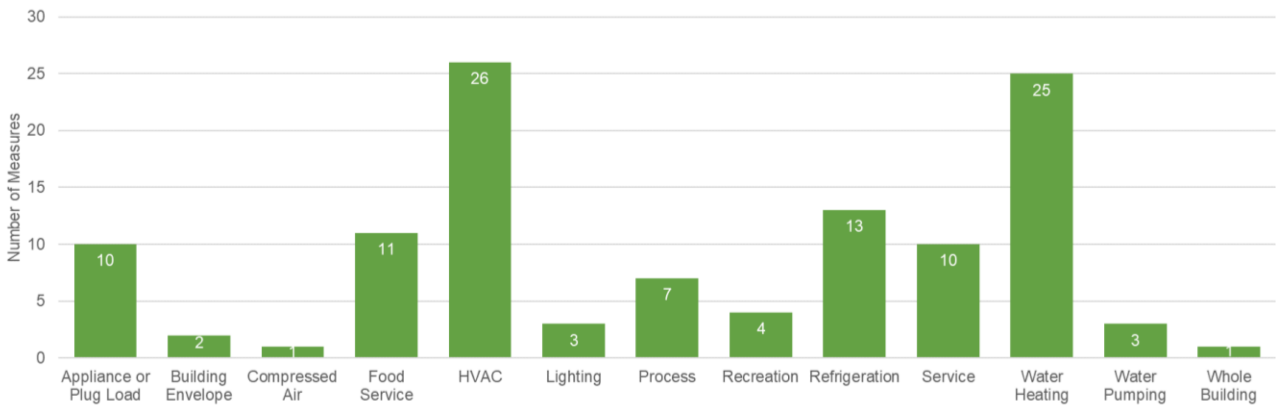
The distribution of measures by end use category that were reviewed for this paper is shown below. Collectively, the 116 measures account for 61% of 2019 savings claims (in terms of kBtu). Two end uses (HVAC, domestic water heating) account for nearly half of the measures included in this analysis.

A *measure* refers to one or more changes in equipment or operating practices that improves the efficiency of energy use. A *measure offering* is defined by the equipment or operating practices that meet specific criteria. Measure offerings are the equivalent of the "products" that are offered to participants of a program. See example below.

Boiler, Commercial Boiler (SWWH005-01)

Measure Offering ID	Capacity (kBtu/hr)	Measure Case Efficiency
A	<=200	0.84 EF
B	<=200	0.92 EF
C	>200	85% TE
D	>200	90% TE

Measure Sample in Current Practices Analysis, by End Use



For each statewide measure, the data utilized in the cost analysis is well-documented and the sources of cost data are cited and retained in the eTRM reference library. Cal TF Staff reviewed the documentation and categorized the source and year of cost data and the analytical method to estimate measure costs for each measure in the analysis sample. This categorization entailed the examination and categorization of four cost categories for each measure: base case material and labor costs and measure case material and labor costs.

Data Sources

Data sources are an important consideration with respect to the overall quality of a measure cost estimate. In general, primary data is preferable to secondary data. As noted above there are considerable challenges and limitations of primary data that is available in the public domain and cost estimates should utilize

[17] An additional 10 measures were analyzed but excluded from the analysis because they have been put on "hold" and are not currently approved.

As of June 18, there were 127 measures approved for the IOU energy efficiency portfolios.

"best available data." Cal TF Staff developed two tiers of data source categorization. The first tier designates cost data as either a primary or secondary data source and the second tier categorizes the actual data source. Examples of primary and secondary data sources are provided in the table below.[18] The table indicates the point in the supply chain (i.e., retailers) and the methods of data collection (i.e., shelf surveys). The primary data sources for this analysis are typically collected through phone surveys, interviews with equipment manufacturers and distributors, from online equipment retailers or suppliers, and from program tracking data and contractor invoices submitted with incentive applications.

Measure Cost Data Source Categorization

Primary Data Sources (Supply chain: method to obtain data)	Secondary Data Sources
Contractors: surveys, invoices, artificial bids	RSMeans [19]
Distributors: surveys, interviews, online price lists	AutoQuotes [20]
Manufacturers: surveys, interviews, cut sheets	U.S. DOE Technical Support Document [21]
Retailers: webscraping, online prices, shelf surveys	Cost Study (non-CA)
Program Data/Invoices: program tracking, incentive applications	

Note that the data sources and analytical methods for measure costs that were obtained from a California-specific study conducted to update measure costs for DEER and/or non-DEER measures (such as WO017) were classified as the data source and method documented in that study, rather than the study itself. This is reasonable because the California update studies were conducted specifically for the purpose of updating measure costs (rather than for a different purpose). For example, the source for the measure case material cost for the residential low-flow showerhead is the WO017 study. The WO017 reports the source of the cost data is contractors and the measure costs were determined by taking a simple average of the data. Thus, for this analysis, the cost data and analytical method for low-flow

[18] Primary data collection refers to the generation of (new) data; primary data should be collected with its intended purpose in mind. "Data which are gathered originally for a certain purpose are known as primary data." — Horace Secrist.

Secondary data (sometimes referred to as unobtrusive data) is data not directly collected by the researcher but that has been initially collected or produced for another purpose. For this reason, secondary data tends to be indicative rather than precise. "The data which are used in an investigation, but which have been gathered originally by someone else for some other purpose are known as secondary data." — Blair.

[19] RSMeans is a common source for construction estimates used by contractors and can be adjusted to account for variation of costs between geographic areas (states, major metropolitan areas across the U.S.). RSMeans data was used for measures in several different end use categories.

[20] AutoQuotes is an online catalog and quotation service of the foodservice equipment and supplies industry. The material costs of food service measures that were reviewed for this analysis were further adjusted to account for volume discounts, based upon professional judgement of staff at the Food Service Technology Center.

[21] A U.S. DOE technical support document (TSD) details technical analyses and results upon that the DOE will rely upon for a final rulemaking to establish federal standards. TSDs typically include engineering analyses, environmental assessment, life-cycle costs, payback periods, and national impact analyses. The measure costs for several water heating measures as well as measures from three other end uses were drawn from TSDs.

showerhead costs were categorized as contractors (a primary data source) and simple average, respectively.

For some measures, the data used to estimate costs was not obtained from a single source and/or a single method. In such cases, Cal TF Staff typically assigned the first source listed in the documentation or made a judgement of the most prominent data. If the documentation were too vague or could not be found, the source was determined to be unknown.

Data Vintage

Data vintage refers to the year that the data was collected or created. For most primary data, the vintage was clearly stated in the explanation of the data sources and methodology to develop the cost estimate. The data vintage for some measures was approximated, particularly if the measure cost was obtained from a secondary reference. The vintage of costs that were developed for the WO017 measure cost update study was assumed to be 2012.

Analytical Methods

Analytical methods are the statistical methods used to analyze the cost data to develop a point estimate. The common methods of cost analysis are summarized below. It is important to note that there is not one single best method to estimate measure costs. The best method depends upon many factors including: the data source and potential biases, data variability, sample size, availability of resources/time to process and analyze data, among others.

Common Analytical Methods

Method	Definition & Applicability	Strengths	Weaknesses
Simple Average	A simple arithmetic average is the most common method to estimate costs if data is limited. Applicability: ▪ Small sample size ▪ Data is from complete random sample of population	Cost and time efficient	Does not represent prices paid
Weighted Average	Costs are calculated as a weighted average to reflect relative proportions (i.e., costs are weighted by program claims or market data) Applicability: ▪ Data not from random sample of population ▪ Variability of products/prices within sample strata	Ensures mix of product types/sales is represented	Influenced by outliers, skewed distributions Data for weighting could be difficult to develop
Median	The median indicates the central tendency of a population. Applicability: ▪ Outliers exist in the sample ▪ Complex, site-specific measures ▪ Costs from experts, such as interviews/surveys of a limited # of market actors	Not influenced by outliers Limited data availability, small sample	Limited applicability Subject to biases Less precise if data not from actual invoices

Method	Definition & Applicability	Strengths	Weaknesses
Regression Analysis	Regression analysis is used to evaluate the relationship between cost and one or more other variables. For example, regression models were constructed to examine the relationship between cost and the normalizing unit, which enabled the estimation of costs when data for a specific sample stratum is missing. Applicability: ▪ Used when need to understand relationship of cost and other product attributes ▪ Interpolation to fill missing data points	Cost efficient way to estimate missing data points	Adequate data required Limited applicability
Hedonic Price Model	A hedonic price model is a specific type of regression analysis used to estimate the relative influence of various product features on an observed price. In the case of energy efficiency measure cost analysis, hedonic price models are used to determine the portion of the measure cost associated with the energy performance of the equipment (e.g. SEER, EER, AFUE, R-value, etc.). Applicability: ▪ Measures with features that could significantly influence price (mass market) ▪ HIMs (due to data requirements and higher cost)	Enables isolation of price variation to energy performance Represent sales volume (POS data)	Data requirements are high Data processing costs Expertise
Built-up Costs	The costs for some measures for which costs are too complex or too specialized are developed by subject matter technical experts. Applicability: ▪ Complex measures/site-specific configurations ▪ It is not possible to isolate features between base and measure scenario ▪ Commercial refrigeration, motors, process	Enables isolation of price variation to energy performance	Requires expertise
Lower Quartile	Lower quartile method is used to estimate costs as the lower quartile of a defined range. Applicability: ▪ Competitive pricing (contractor bids) when lower bids are more representative of actual prices paid ▪ Service measures (HVAC QI/QM)	Can account for contractor mark-ups	Limited applicability

Sources:

Ting, M., M. Rufo, and J. Loper. 2013. "Measure costs – the forgotten child of energy efficiency analysis." ECEEE Summer Study Proceedings. Pp. 2081 – 2091.

Ting, M. (Itron, Inc.) 2014. "Energy Efficiency Measure Cost Studies." SEE Action Webinar – EM&V Working Group. September 24.

Itron, Inc. 2014. *2010-2012 WO017 Ex Ante Measure Cost Study Final Report.* Prepared for the California Public Utilities Commission.

Cal TF Staff analysis of approved statewide measures.

Regional Technical Forum (RTF). 2015. *Roadmap for the Assessment of Energy Efficiency Measures.* December 8.

Material Cost Data

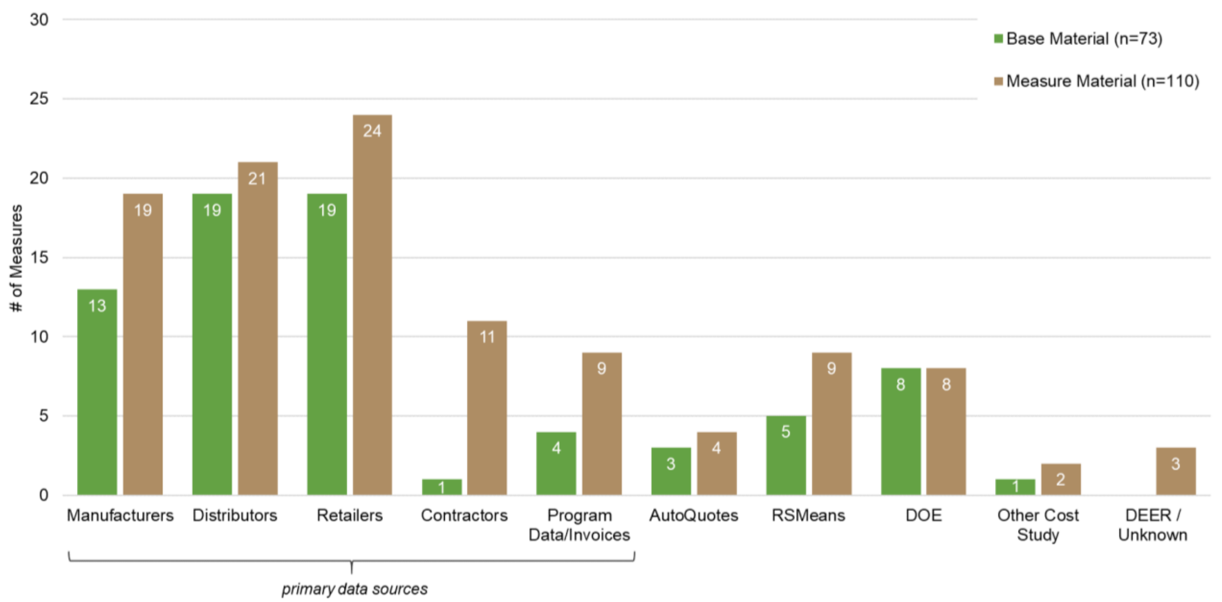
This section summarizes results of Cal TF Staff tabulation of base case and measure case material cost data sources.

As shown below, the most prominent data sources for material costs are equipment manufacturers, distributors, and retailers. Key observations include:

- Material costs for 80% of the measures in the analysis were derived from primary data sources (data collected from manufacturers, distributors, retailers, program data/invoices).
- Secondary data sources include RSMeans, U.S. DOE technical support documents, and AutoQuotes.
- Some measures for which material costs were obtained from the WO017 report or the 2008 DEER update study could not be identified in the referenced report or the data source was not clearly documented. For these measures, the data source was classified as "DEER / Unknown".

Interestingly, the analysis of material cost data sources revealed that for almost 30% of the measures the base case and measure case materials costs were derived from different data sources.[22] While it is expected that not all costs are developed from the same source due to data availability or other limitations, using the same data source will help to ensure a true "apples to apples" comparison of baseline and measure costs.

Material Cost Data Sources

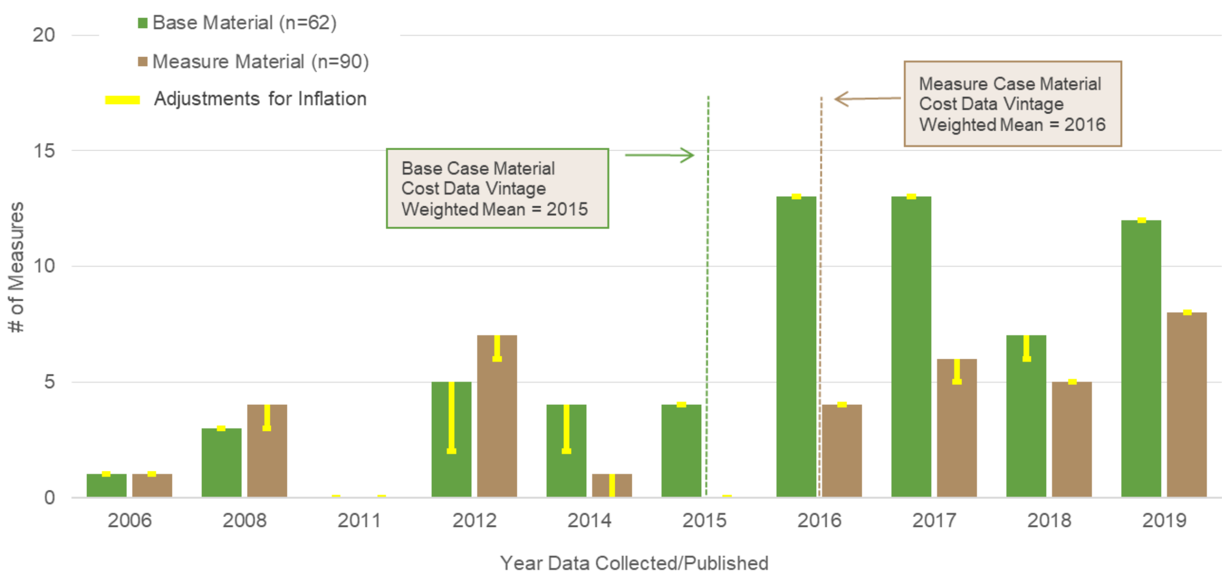


[22] This comparison excludes measures for which base case costs are not applicable.

The vintage of cost data is an important consideration to ensure measure cost estimates reflect current market conditions. The figure below shows the distribution of measures by year the measure cost data was obtained (if primary data) and/or reported (if secondary source). The number of measures for which costs were adjusted for inflation is reflected in the bright yellow lines in the figure. For example, the chart indicates that the base case material costs for five (5) measures were obtained in 2012. The bright yellow line indicates that the costs of three (3) measures were adjusted for inflation and converted to 2018 or 2019 values. This chart also indicates the mean vintage, weighted by the measure impacts claimed in 2019.

- Material cost data for most measures was obtained in 2012 or later; cost data obtained in 2012 mostly likely was obtained from the WO017 study.
- Cost data for some measures was adjusted for inflation (converted to 2018 or 2019 values), but most adjustments were made to data sourced prior to 2015.
- The weighted mean vintage of base case and measure case material cost data weighted by impacts claimed in 2019 is 2015 and 2016, respectively. On average material cost data is four to five years old.

Vintage of Material Cost Data



Consistency checks on the data vintage and adjustments for inflation revealed:

- Almost one-fourth (25%) of the measure case costs were estimated with measure cost data that was of a different vintage of the labor cost data. (This consistency check included 77 observations for which the data vintage was known for both the labor and material cost data.)
- A portion (14%) of the measure case costs were estimated with data that was not consistently adjusted for inflation. This means that one cost element (material cost or labor cost) was adjusted for inflation, not both.

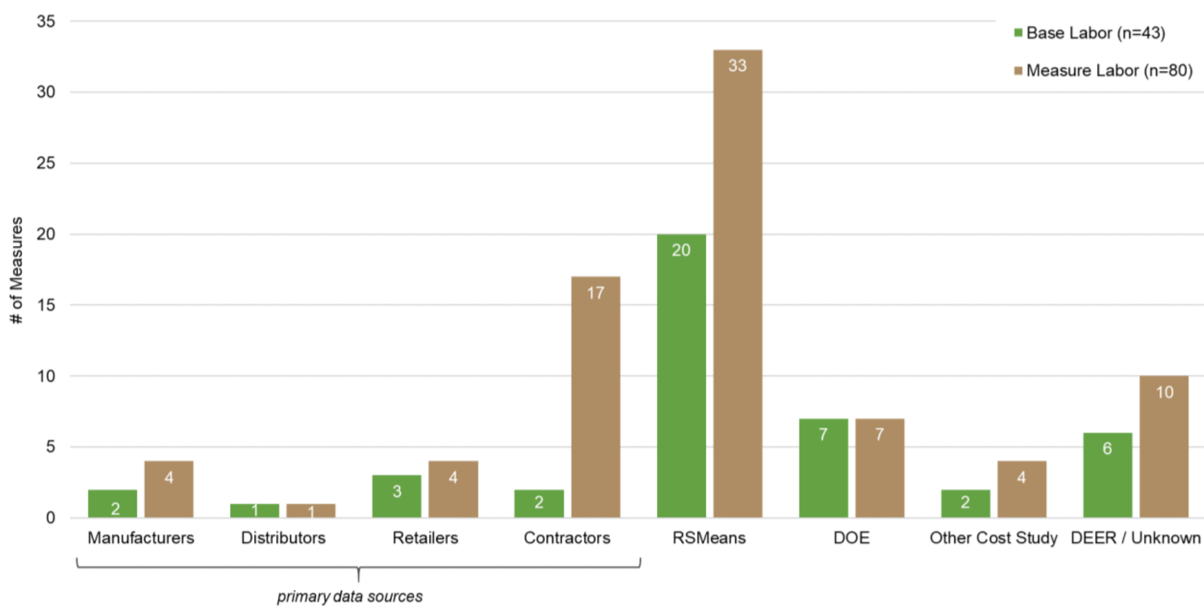
Again, to ensure accurate comparison of baseline and measure costs, inconsistencies such as these should be avoided if possible.

Installation Labor Cost Data

Installation labor costs represent the costs to install both the baseline and measure case equipment; baseline labor costs are excluded for new construction application types and are typically assumed to equal measure case installation costs for most normal replacement application types.

- In contrast to measure cost data summarized above, installation labor costs for most measures were derived from secondary sources. As shown in the figure below, labor costs were derived from secondary data sources for 81% and 68% of the measures for base and measure installation labor costs, respectively. This is expected due to the limited availability and proprietary nature of labor rates, and the fact that contractor estimates rarely separate labor from material costs. Additionally, the primary data sources for material costs shown above generally are not sources for installation labor costs (manufacturers, distributors, and retailers, for example, generally do not install equipment therefore are not a source of installation costs). Secondary sources such as RSMeans are a cost-effective and widely accepted source to estimate installation costs.
- RSMeans – a common source for estimating used by the contracting industry - is the most common source of labor cost data (used for 47% and 41% of the measures for base and measure case labor costs, respectively).

Installation Labor Cost Data Sources

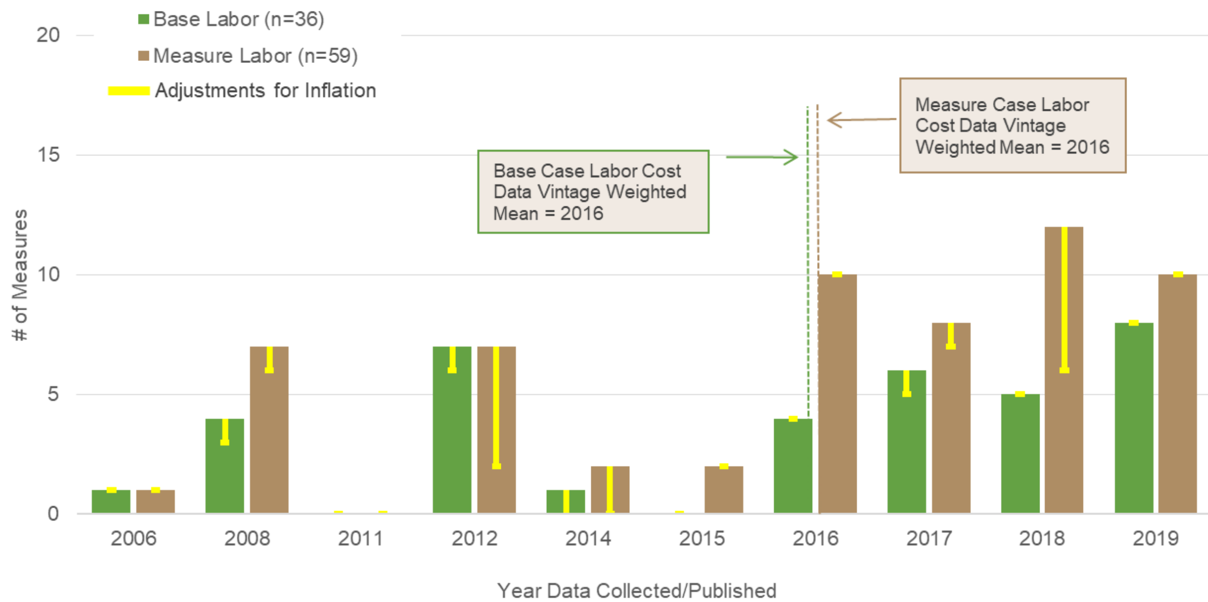


The distribution of measures by the vintage of installation labor cost data is shown below. Similar to the material cost vintage chart, the number of measures for which costs were adjusted for inflation is reflected in the bright yellow lines in the figure. This chart also indicates the mean vintage of labor cost data, weighted by the measure impacts claimed in 2019.

- Almost two-thirds (64%) of the measures used data sourced after 2014 to develop baseline installation labor costs and 71% of the measures utilized data sourced after 2014 to develop measure case installation labor costs.

- The distribution shows some emphasis on years of the most recent California measure cost studies (2008 and 2012)
- Some but not all labor costs derived from data prior to 2019 were adjusted for inflation, and inflation adjustments were inconsistent.
- The average vintage (weighted by 2019 impacts) of base and measure case labor cost data is 2016; on average labor cost data is four years old.

Vintage of Installation Labor Cost Data



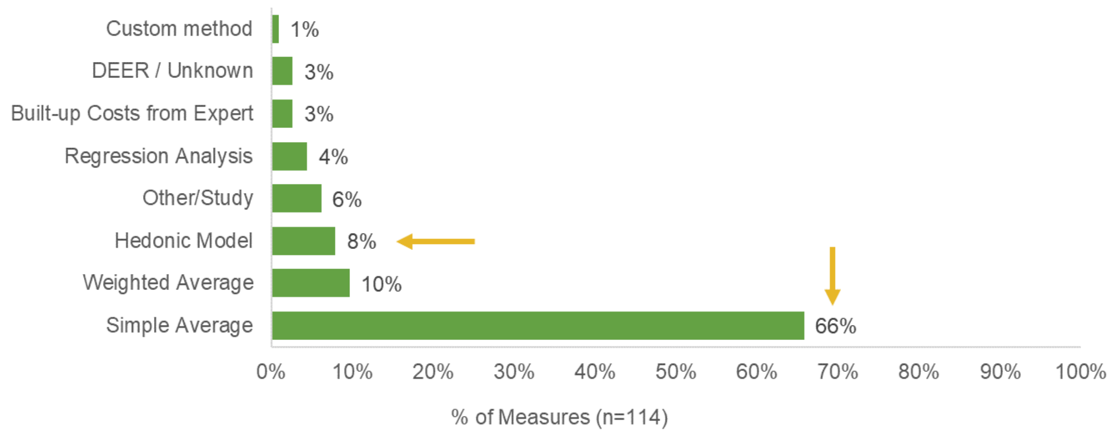
Analytical Methods

The methods for calculating the base and measure case point estimates used for the incremental or full measure cost calculation were categorized as simple average, weighted average, regression analysis, hedonic price model, and built-up costs by an expert, adopted from another cost study, or other custom method. Measures for which the analytical method was not documented or documented as DEER and could not be identified in a DEER study, was labeled as “DEER / Unknown”. It is important to note here that while the methods used for some measures was easily categorized, for others the approach was more complex and involved multiple methods.

As noted above, WO017 used hedonic price models to estimate measure costs for about 75% of the measures covered by that study. Use of hedonic models increased after the 2001 incremental cost study and is the preferred method as it enables the isolation of costs that account for just the energy performance of the equipment. Hedonic price models are the preferred approach for many measure groups for this reason.[23]

The figure table below summarizes the methods to estimate the material cost portion measure case costs. The most significant result is that the majority of material costs were estimated by taking a simple average of a small number of data points. This is not a surprising result as the IOUs have updated costs and transitioned away from using WO017 values. Moreover, the data collection and analyses used for WO017 is impractical for utility staff to replicate when measure costs are updated one-by-one.

Measure Case Material Cost Analytical Methods



The table below summarizes analytical methods to estimate material measure costs by end use. This table is useful because it reveals the extent of variation within end uses when perhaps there could and should be more consistency. For example, there is variation among methods to estimate costs in largest end uses represented – HVAC and water heating. These end uses contribute to a lot of the divergence from the WO017 study for which most (but not all) HVAC and water heating costs were developed from hedonic cost models. This table is also useful to pinpoint measures for which costs were calculated as a simple average, that might be candidates for more rigorous data collection and/or analysis for future cost updates (particularly any HIMs).

[23] Itron, Inc. 2014. *2010-2012 WO017 Ex Ante Measure Cost Study Final Report.* Prepared for the California Public Utilities Commission. P. 5-18.

Measure Case Material Cost Analytical Methods, by End Use

End Use	Hedonic Model	Regression Analysis	Simple Average	Weighted Average	Other Study	Built-up Costs from Expert	DEER / Unknown	Custom method
Appliance or Plug Load	3	1	5		1			
Building Envelope	1		1					
Compressed Air		1						
Food Service		1	8	2				
HVAC	3	2	17	1			1	1
Lighting				3				
Process			7					
Recreation			4					
Refrigeration			5	3	1	3	1	
Service			9					
Water Heating	2		16	2	4		1	
Water Pumping			2		1			
Whole Building			1					
TOTAL	**9**	**5**	**75**	**11**	**7**	**3**	**3**	**1**

Key Findings

Data Sources

- Material equipment cost data sources for most measures were primary sources; secondary sources are utilized for small number of niche measures.
- Labor installation costs for most measures are determined from secondary sources, primarily from RSMeans. This finding is fairly consistent with the most recent measure cost update study, WO017.
- The costs for many measures for which primary data was utilized – particularly manufacturer and distributor/supply house list prices – do not reflect average prices actually paid (because list prices do not reflect the quantity of units sold), and published list prices to not account for volume discounts awarded to installation contractors, contractor markups, etc.
- Equipment and installation costs are central to cost analysis current practices but other life cycle cost components, such as ongoing operations and maintenance (O&M) and disposal costs are not well studied and were rarely included in cost calculations. This is logical if 1) the O&M costs are assumed to be the same for the base and measure cases for normal replacement and new construction measures and they would cancel out in the incremental measure cost calculation, and 2) the cost of documenting and estimating O&M costs might be prohibitive for non-high impact measures in the portfolio.

Data Vintage

- On average, material and labor cost data used to estimate measure costs are four to five years old; data for some measures dates to 2006 and 2008 not all of which was adjusted for inflation.
- Conversion of cost data to current year values to adjust for inflation was inconsistent across measures (some measure costs were adjusted and some not), inconsistent across data vintage (not all data of older vintages was adjusted) and even inconsistent within same measure (material costs or labor costs were adjusted, but not both).

Methods

- The most significant result is that the majority of material costs were estimated by taking a simple average of a small number of data points. This is not a surprising result as the IOUs have updated costs and transitioned away from using WO017 values.
- The majority of measure cost estimates do not reflect average prices paid by the overall population of interest (i.e., not weighted by claims or sales data).
- Precision of the point estimates were not provided in the cost documentation, also not surprising given the majority of estimates were calculated as a simple average.

PROPOSED GUIDELINES FOR MEASURE COST ESTIMATION

The importance of cost in the measure cost effectiveness TRC metric, the transition of program design and implementation to third-party (3P) organizations, and the ability of 3Ps to propose deemed measures all point to the need for a framework to estimate measure costs.

The overarching *fundamental principles* that serve as a framework for the proposed guidelines are as follows:

Comply with regulatory requirements. Measure costs should conform to the TRC calculation requirements as well as the cost basis and baseline assumptions for each measure application type. The cost analysis and resultant per-unit cost values must be reviewed and approved by the CPUC to be implemented in the IOU portfolios.

Represent average prices actually paid by customers. Because the TRC test evaluates an energy efficiency measure or program in part based upon the participants' costs, the estimated measure costs should reflect prices actually paid by customers.

Represent current market conditions. Estimated measure costs should reflect equipment and labor costs that would be incurred during the period in which the measure is approved to be implemented.

Represent an "apples-to-apples" comparison between base and measure case costs, using cost data of the same vintage. For measures that require the incremental cost rather than full measure cost (normal replacement and new construction), the baseline and measure case costs should be based on data collected from similar sources of the same vintage and computed using the same methodology.

Represent costs associated the change in energy performance from the baseline to measure case of the technology. For measures that require the incremental cost rather than full measure cost for the TRC calculation, the incremental cost should reflect the cost difference associated with the increase of energy performance between the base and measure case.

Investment in measure cost data development and analyses should be commensurate with the measure contribution of impacts to the portfolio. There is not one single best data source or method to estimate measure costs. Among the many considerations is the measure expected contribution to the deemed energy efficiency portfolio relative to other measures. High impact measures warrant a higher investment (i.e., more rigorous data collection and analysis) than others, particularly measures on the margin of being not cost-effective. The measure cost estimates of HIMs also warrants independent validation.

Be Transparent and well documented to foster consistency and reproducibility. Underlying principles of the Cal TF for the consolidation to statewide measures, the design and development of the eTRM, and the new measure development process for 3P measure proposals include transparency, consistency, reproducibility, and accessibility. These principles apply to all aspects of future statewide measure development and updates.

The proposed guidelines for measure cost estimation are summarized below. These draw from a variety of resources including: Cal TF Staff experience from reviewing IOU-specific workpapers during the consolidation process to develop statewide measures, familiarity of CPUC regulatory requirements and

CPUC Staff/ex ante review consultant requirements for workpapers submitted for review, recommendations provided in the WO017 study, insights from consultants that have conducted measure cost studies, Cal TF Staff experience with cost-effectiveness analyses, and input from the Cal TF measure cost guidance subcommittee.

Guideline 1: Develop Measure Costs that Align with TRC and Claims Requirements

The costs to calculate the TRC, the primary indicator of cost effectiveness for IOU energy efficiency programs), must include "all equipment costs, installation, O&M, cost of removal (less salvage value), and administration costs" regardless of who pays for them.[24]

The cost used in the cost effectiveness calculation depends upon the measure application type. *Incremental measure costs* (IMC) – the cost of installing one measure or technology (efficient measure case) instead of another (base case – code compliant or ISP) – equals the difference between the base case and the measure case full measure cost. This cost basis is used for normal replacement (NR) and new construction (NC) measure application types. *Full measure cost* (FMC) represents the full cost associated with installing a measure and is used in the cost effectiveness calculation for all other application types.

Importantly, measure costs used to calculate cost effectiveness must align with the required baseline definitions and corresponding cost basis. The requirements for each measure application type are summarized in the table below.

Measure Cost Requirements by Measure Application Type

Measure Application Type	Description	1st Baseline Cost	2nd Baseline Cost
Accelerated Replacement (AR)	Measure is installed when the existing equipment is still operational. This type includes Repair Eligible and Repair Indefinitely measures.	Full measure cost (realized when measure is installed)	Incremental measure cost over code/standard equipment (realized after the RUL period)
Normal Replacement (NR)	Measure is installed when the existing equipment fails, or maintenance requires replacement.	Incremental cost of measure over code/standard equipment	N/A
New Construction (NC)	Measure is installed during construction instead of code/standard equipment.	Incremental cost of measure over code/standard equipment	N/A
Add-on Equipment (AOE)	Measure is installed to pre-existing "host" equipment that is still operational.	Full measure cost	N/A

[24] California Public Utilities Commission (CPUC). 2011. *California Standard Practice Manual. Economic Analysis of Demand-Side Programs and Projects.* October. P. 18.

Measure Application Type	Description	1st Baseline Cost	2nd Baseline Cost
Building Weatherization (BW)	Measure includes improvements to nonmechanical building structures or existing equipment that is essential to building function without maintenance.	Full measure cost	N/A
Behavioral (BRO-Bhv)	Measure includes informational or educational programs that influence energy-related practices.	Full measure cost	N/A
Retrocommissioning (BRO-RCx)	Measure is installed/applied as part of retro-commissioning.	Full measure cost	N/A
Operational (BRO-Op)	Measures that improve the efficient operation of installed equipment.	Full measure cost	N/A

Source: Ex Ante Measure Cost Specification (12/22/2015) and Statewide Deemed Workpaper Rulebook (version 3.0, 1/1/2020)

The accelerated replacement cost (ARC) is the FMC of the efficiency measure, reduced by the net present value of the FMC that would have been incurred to install the standard practice second baseline equipment at the end of the remaining useful life (RUL) period.[25]

Measure cost should be documented in a manner that makes it easy for measure users to use the data for related tasks. The two tasks of calculating cost-effectiveness through the CET tool and submitting claims to CEDARS both require cost to be reported in the same format. Documenting costs with respect to first and second baselines will facilitate this need. The table above shows how cost varies with measure application type and the first and second baselines.

Guideline 2: Costs to be Included in Measure Cost Estimate

The participant cost portion of the TRC calculation includes the upfront equipment and installation costs as well as costs to operate and maintain the measure, as well as O&M and removal (less salvage value) costs. This guideline provides measure developers with definitions of these costs and circumstances when certain cost components might be excluded from the calculation.

The costs of statewide measures are categorized into material costs and labor costs, both of which should be estimated for both base case and measure case (if applicable).

> **Material costs** include all “equipment costs” as well as the cost of “non-equipment material costs” that are required to install the measure. For some measures, the non-equipment material

[25] The *Statewide Deemed Workpaper Rulebook, Version 3.0* compiles all CPUC rules and guidance the IOUs must follow for developing a deemed measure. See:

Pacific Gas and Electric (PG&E), San Diego Gas & Electric (SDG&E), Southern California Gas Company (SCG), and Southern California Edison (SCE). 2020. *Statewide Deemed Workpaper Rulebook. Version 3.0.* January 1. The ARC is calculated using the following formula:

$$ARC = FMC - \frac{FMC - IMC}{(1+D)^{RUL}}$$

D represents the CPUC-adopted PA discount rate, which are subject to change.

costs are assumed to be the same for the baseline and measure case and thus are not included in the cost calculation (see below).

Permit fees should also be considered – such as fees issued by the Division of the State Architect (DSA) and the Office of Statewide Health Planning and Development (OSHPD) for public hospitals and schools. However, such fees are not likely to be directly related to the energy performance of the equipment and are likely to be the same for the baseline and measure case, as such they are typically excluded from the cost calculation.

Labor costs refers the labor costs required to install the measure, or "non-equipment installation costs". The inputs to compute labor costs are typically the hourly labor rate and quantity of labor hours. Labor costs might also include operations and maintenance costs incurred throughout the measure life.[26] For some measures, the non-equipment installation and/or O&M costs are assumed to be the same for the baseline and measure case and thus are not included in the cost calculation (see below).

Not all cost components defined above are necessarily included in the cost calculation. Costs that are included in the cost calculation depend upon two primary factors – measure application type and if the baseline is a similar technology or a significantly different technology than the measure case.

Normal replacement (NR) and new construction (NC): The cost of NR or NC measures typically does not require estimating non-equipment material or installation costs if these costs are determined (or assumed) to be the same for the base and measure case and thus cancel each other out in the incremental measure cost calculation. An example of this is when the measure case is simply a higher efficiency version of the base case and the cost to install the equipment is the same regardless.

An important exception, however, is when the measure case is not simply a higher-efficiency version of the same technology but rather is significantly different, such as when a tankless water heater is chosen to replace a storage tank water heater. (WO017 refers to this as a "cross-technology baseline".) The non-equipment material and installation costs associated with the measure (tankless water heater) and the baseline equipment (storage tank water heater) are not necessarily identical, and accounting for the differences in non-equipment material and installation costs is important to correctly estimate incremental measure costs.

Accelerated replacement (AR), add-on equipment (AOE), building weatherization (BW) and behavior, retro-commissioning, and operation (BRO): In general, equipment material costs, non-equipment material costs, and installation costs are needed to estimate the incremental costs of all AR, AOE, BW, and BRO measures. AR and AOE are currently most common in the portfolio. The incremental measure cost of an AOE measure is equal to the full, installed measure cost, which includes all material and installation costs. The incremental measure cost of an AR measure is calculated on a dual baseline basis: equal to full measure cost of the installed measure cost during the RUL of the base case equipment being replaced, after which it is equal to the incremental cost between the measure and the code-compliant baseline equipment.

[26] Cal TF Staff review of current practices did not identify measures for which O&M costs were included in the calculation. In practice "non-equipment material costs" might be difficult to estimate and it might be cost-prohibitive to include these costs in the calculation, especially if the measure is not a high impact measure.

The documentation of the measure cost analysis should explain which cost components were excluded and the rationale for doing so (see Guideline 9 below).

Guideline 3: Data Sources and Analytical Methods

This guideline is intended to help measure developers identify and assess optional approaches to identify the best available data and analytic method that will result in a defensible measure cost estimate. The data collection and analysis approach should necessarily address data requirements to estimate all cost elements (full cost of both baseline and measure case equipment and labor) and other weighting factors and adjustments (such as locational adjustment factors, inflationary adjustments) if warranted.

The data collection and analysis approach should consider the following:

- *Equipment supply chain and point of transaction:* Consider the point in the supply chain at which the transaction occurs so the data reflects the average market price paid; also consider the point in the supply chain that the desired data will be available. (For example, residential refrigerators are purchased by the customer through retailers. Thus, the data source should be at the retailer point in the supply chain.)
- *Data needs:* Consider data that will be needed to estimate all components of the measure cost (equipment and non-equipment material cost, labor installation, O&M), and that cost estimates should ideally represent average price paid rather than average of prices listed.
- *Data availability:* Consider if data needed will be realistically and cost-effectively available and identify alternative source(s). Confidentiality and competitive sensitivity create significant barriers to data availability.
- *Data collection costs:* Consider costs to purchase or collect data; depending on the source and data requirements of the analytical method, data collection can be costly.
- *Data processing:* Consider how missing data points will be addressed and expect to have to translate data from different sources to a common format for analysis and to enable pairwise comparisons of features. Depending on the data source, data will need to be coded to be used in regression and hedonic price analysis.
- *Data limitations and potential biases:* Cost structures may vary considerably across companies, such as distributors, thus data should be obtained from as diverse and large of a sample as possible. For example, surveys of market actors may have self-response/social desirability bias and could be less precise. See Appendix A.
- *Analytical method:* The analytical method will determine data requirements; be mindful that some methods are not appropriate or even possible for all measures. For example, a hedonic price model requires many variables to represent the multitude of attributes that drive cost and is data-intense compared to other methods, however, this method is based upon large samples and will isolate the incremental price change due to energy performance difference.
- *Data sources and methods used to estimate costs for similar measures:* Consider the cost analysis approach that has been used for other measures in the end use/technology type.
- *Data validation:* Determine how cost estimates (for HIMs, specifically) can be validated to ensure estimates are reasonable and defensible, particularly given identified limitations and biases.

The following tables provide guidelines for measure developers for data sources and analytic methods to estimate material costs. These tables are intended to help measure developers identify and assess optional approaches and are not intended to prescribe one particular strategy. The information provided is generalized and might not apply to all measures within the use category. Finally, the tables include most but not all use categories. The excluded use categories– Recreation, Process, Water Pumping, Compressed Air – include measures that are unique and require specific knowledge of those markets to identify the most appropriate data sources. Since there are fewer measures in these categories, neither standard data sources nor typical analytical methods have emerged. A use category of "Other" has been included for these more unique categories, where the simple average, lower quartile, and/or built-up costs by an expert methods are appropriate. These use categories could become areas for future definition if the number of measures grows.

While the data sources and analytical methods for material cost may have guidance that varies by use category, labor cost has a similar issue for any use category. As described before, labor costs are more difficult to document due to the limited availability and proprietary nature of labor rates, and the fact that contractor estimates rarely separate labor from material costs. Therefore, the general guidance to document base and measure case labor costs is to use RSMeans, an industry-accepted secondary source, if a primary data collection effort cannot cost efficiently produce a statistically significant labor cost estimate. Regardless of the data source and method, the estimation of labor costs should use California-based labor rates, and the assumed labor hours and all association assumptions should be documented.

Summary of Data Sources and Methods - HVAC

Use Category	Data Sources	Analytical Method	Pros & Cons
HVAC (Res & Nonres) *In general, HVAC equipment costs vary according to many variables: project size, transaction type, efficiency, etc. Costs also vary due to promotions (either from manufacturers or distributors), project type, project size, and competitive nature of transaction.* *Features (i.e., staging, compressor type, controls, motor type) between various models should be documented, as prices can change dramatically. Sales to small, medium, and large contractors and/or customers also vary.*	Distributor price lists (online or direct from distributor) CEC, AHRI data, and/or cut sheets to determine pairwise matching of attributes	Hedonic cost model ** Best for HIMs or if analysis will include multiple measures*	(Pro) Isolates EE portion of cost diff (Con) Price lists online could be limited and not reflect equipment availability and/or combinations of components, particularly for nonresidential (Con) Barriers to obtaining data w/out existing relationships with equipment distributors (Con) No installation costs (Con) List prices do not reflect actual prices paid and may exclude contractor markups and volume discounts (Con) No sales volume
	Distributor price lists (online or direct from distributor) CEC, AHRI data, and/or cut sheets to determine pairwise matching of attributes	Weighted Average or Simple Average	(Con) Price lists could be limited and not reflect equipment availability and/or combinations of components, particularly for nonresidential (Con) Barriers to obtaining data w/out existing relationships with equipment distributors (Con) No installation costs (Con) List prices do not reflect actual prices paid and may exclude contractor markups and volume discounts (Con) Sales volume/market share for weighting could be difficult to develop (Con) Does not isolate EE portion of cost diff
	Contractors – artificial bids	Lower Quartile	(Pro) Could include installation cost (Pro) Accounts for competitive bid pricing (Con) Small sample (Con) Could be difficult to develop specs to meet all baseline and measure case scenarios (Con) Not applicable if high variability of costs within sample stratum

Use Category	Data Sources	Analytical Method	👍 Pros & Cons 👎
Service HVAC Maintenance	Contractors – invoices	Simple Average	👍 Can include installation costs 👎 Limited sample
	Contractors – artificial bids	Lower Quartile	👍 Can include installation costs 👍 Reflects competitive bid pricing 👎 Limited sample

Summary of Data Sources and Methods – Service & Domestic Hot Water

Use Category	Data Sources	Analytical Method	👍 Pros & Cons 👎
Service & Domestic Hot Water Water Heating Equip. (Res & Nonres)	Distributor price lists (online or direct from distributor/supplier) CEC, AHRI data, and/or cut sheets to determine pairwise matching of attributes	Hedonic cost model ** Best for HIMs or if analysis will include multiple measures*	👍 Isolates EE portion of cost diff 👎 Price lists online could be limited and not reflect equipment availability and/or combinations of components, particularly for nonresidential 👎 Barriers to obtaining data w/out existing relationships with equipment distributors 👎 No installation costs 👎 List prices do not reflect actual prices paid and may exclude contractor markups and volume discounts 👎 No sales volume
		Weighted Average or Simple Average	👎 Price lists online could be limited and not reflect equipment availability and/or combinations of components, particularly for nonresidential 👎 Barriers to obtaining data w/out existing relationships with equipment distributors 👎 No installation costs 👎 List prices do not reflect actual prices paid and may exclude contractor markups and volume discounts 👎 Sales volume/market share for weighting could be difficult to develop 👎 Does not isolate EE portion of cost diff

Use Category	Data Sources	Analytical Method	Pros & Cons
	Contractors – artificial bids	Lower Quartile	👍 Could include installation cost 👍 Accounts for competitive bid pricing 👎 Small sample 👎 Could be difficult to develop specs to meet all baseline and measure case scenarios 👎 Not applicable if high variability of costs within sample stratum
Service & Domestic Hot Water Showerheads Aerators (Res & Nonres)	DI Program Contractors - invoices	Simple Average	👍 Cost efficient 👎 Small sample sizes 👎 Does not provide costs for baseline 👎 Does not isolate EE portion of cost diff
	Retailer – webscraping	Weighted Average Simple Average	👍 Large samples 👍 Cost efficient 👎 List prices do not reflect actual prices paid 👎 Sales volume/market share for weighting could be difficult to develop 👎 Does not isolate EE portion of cost diff

Summary of Data Sources and Methods - Lighting

Use Category	Data Sources	Analytical Method	👍 Pros & Cons 👎
Lighting (Res)	Retailer – Shelf surveys	Hedonic cost model	👍 Includes product features 👍 Isolates EE portion of cost diff 👎 Data collection requires time and field teams 👎 No sales volume
	Retailer – webscraping	Weighted Average or Simple Average	👍 Large samples 👍 Cost efficient 👎 List prices do not reflect actual prices paid 👎 Sales volume/market share for weighting could be difficult to develop 👎 Does not isolate EE portion of cost diff
Lighting (Nonres)	Distributor price lists Cut sheets to determine pairwise matching of attributes	Weighted Average Simple Average	👎 Barriers to obtaining data w/out existing relationships 👎 List prices do not reflect actual prices paid and may exclude contractor markups and volume discounts 👎 No installation costs 👎 Sales volume/market share for weighting could be difficult to develop 👎 Does not isolate EE portion of cost diff 👎 No sales volume
	Contractors – artificial bids	Lower Quartile	👍 Could include installation cost 👍 Accounts for competitive bid pricing 👎 Small sample 👎 Could be difficult to develop specs to meet all baseline and measure case scenarios 👎 Not applicable if high variability of costs within sample stratum

CALIFORNIA TECHNICAL FORUM

Summary of Data Sources and Methods – Other Use Categories

Use Category	Data Sources	Analytical Method	Pros & Cons
Appliance or Plug Load Appliances Consumer Electronics Room AC	Retailer – Point of sale (POS) data	Hedonic cost model ** Best for HIMs or if analysis will include multiple measures*	(Pro) Includes product features (Pro) Isolates EE portion of cost differences (Pro) Large sample size (Pro) Includes sales volumes (Pro) Actual prices paid (Con) Data purchase/collection costs can be high (Con) Data requirements and data processing needs are high
	Retailer – webscraping	Weighted Average Simple Average	(Pro) Large sample size (Pro) Cost efficient (Con) List prices do not reflect actual prices paid (Con) Sales volume/market share for weighting could be difficult to develop (Con) Does not isolate EE portion of cost differences
Commercial Refrigeration	(not applicable)	Built-up Costs	(Pro) Could include installation cost (Pro) Reflects all components of complex projects (Con) (Pro) Requires industry expertise (Con) No sales volume
Food Service	AutoQuotes	Simple Average or Median	(Pro) Cost efficient (Pro) Industry accepted quote service (Con) List prices do not reflect prices charged to customers, unless estimate of discount developed (Con) No sales volume

Use Category	Data Sources	Analytical Method	Pros & Cons
Other Use Categories Recreation Process Water Pumping Compressed Air	Contractors – invoices	Simple Average	Can include installation costs Limited sample
	Contractors – artificial bids	Lower Quartile	Can include installation costs Reflects competitive bid pricing Limited sample
	(not applicable)	Built-up Costs	Could include installation cost Reflects all components of complex projects Requires industry expertise No sales volume

Guideline 4: Develop Separate Estimates for Material Costs and Installation Labor

Equipment material costs and labor costs must be estimated separately (for both baseline and measure), even though these cost elements are combined to compute the full measure cost. Separate estimates will encourage transparency, improve documentation, and will better inform future measure updates. This practice will also ensure that measure developers and reviewers can conduct an “apples to apples” comparison between baseline and measure cost data, between costs across similar measures and/or with cost estimates developed for other states/regions that might be used for benchmarking or validation purposes.

Guideline 5: Develop Costs that Align with Base and Measure Case Definitions, Using the Same Data Sources, of the Same Vintage, and Same Analytical Methods

The purpose of this guideline is to ensure symmetry between estimated costs for the baseline and measure case equipment. First, cost estimates should be developed such that they align with the base case and measure case specifications. Second, to enable an “apples to apples” comparison of baseline and measure costs, the analysis should obtain data from the same source and of the same vintage. Moreover, the same analytical methods should be used to calculate base and measure costs. Reasons for deviations should be documented.

Guideline 6: Cost Estimates Should Reflect the California Market

Data collected from a state or region outside of California should be adjusted as necessary to reflect costs in California.[27] Adjustment factors should not be applied to price data collected online, assuming end users both within and outside of California will pay the same price for equipment. Locational adjustments to reflect price differences between more localized regions *within* the State of California are not necessary for statewide measures; locational adjustment factors for more local regions could complicate the cost analysis if the result is already within the error of other inputs. For example, cost values should not vary by climate zone unless other parameters values are more precise.

Guideline 7: Estimated Measure Costs Should Represent Average of Costs Actually Paid

Measure cost estimates should reflect average prices paid in the marketplace. Depending on the data sources and analysis method, this requires weighting cost estimates by either sales volume (for baseline) or program claims data (for measure case). Depending on the variability of the cost data, the absence of

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[27] An adjustment factor to convert cost values representing another region or a national average to California values can be developing using the RSMeans state price indices.

weighted cost values could over- or under-estimate measure costs, particularly for measures for which there is higher variation of costs for equipment within the same measure offering.

In practice, this is difficult to implement, given challenges associated with obtaining and developing data to be used as weighting factors.

Guideline 8: Independently Validate Cost Estimates

One of the distinguishing features of the WO017 study that should be considered a best practice – particularly for HIMs – is the validation of measure cost estimates.[28] Independent validation refers to cross-checking estimated values against a small number of "out of sample" data points (data gathered from one or more different sources than what was used for the analysis). *Validation is beneficial, particularly for HIMs and measures that might be on the margin of meeting (or failing) cost-effectiveness requirements.* Depending on the data sources used to develop the measure cost estimate, sources to validate costs include:

- Published list prices
- Artificial contractor bids
- Customer invoices
- Online retailer or supplier price lists
- RSMeans and other secondary resources
- Market actor interviews
- Title 24 CASE reports

Data limitations might prohibit or limit this practice; out of sample data sources might not exist for large capital equipment or for technologies that are in an early phase of commercialization.

Guideline 9: Document Analytical Methods, Values, and Sources of All Data Used for the Measure Cost Calculation

Measure developers must document all methods, values, and data sources to estimate measure costs. The purpose of this guideline is to ensure transparency and reproducibility of measure cost estimates. Importantly, this guideline will also ensure transfer of knowledge to other measure developers and for measure updates.

There are four fields in the statewide measure characterization for this purpose: base and measure case material costs, and base and measure case labor costs. (The specific cost components included in the material and labor cost categories were explained in Guideline 2 above.) In general, the cost analysis documentation should reflect understanding of the market through which the technology is bought/sold, explain the source(s) and nature (variability, sample size, etc.) of the cost data, and explain the analytic method to derive the cost estimates.

[28] Itron, Inc. 2014. *2010-2012 WO017 Ex Ante Measure Cost Study Final Report.* Prepared for the California Public Utilities Commission. P. 2-30.

Specifically, the documentation should explain:[29]

- Equipment material cost data for baseline and measure (data source, data vintage, sample size, variability)
- Installation cost data (data source, data vintage, sample size, description of labor required, and any hourly labor rate and quantity of labor hours)
- O&M cost data (data source, data vintage, description of O&M required)
- Data processing, such as treatment of outliers and how missing data points are addressed
- The analytical method used to estimate costs and the rationale for choosing the method
- Development and use of weighting factors, such as sales volume or claims (data source, data vintage, explanation of how factors were developed and applied in the analysis)
- Development and use of locational adjustment factors, if applicable (data source, values, and date)
- Development and use of inflation adjustment factor/price index, if applicable (data source, values, date)
- Assumptions and computation to convert cost estimate to the normalizing unit (must be same as savings/demand reduction normalizing unit)

Guideline 10: Vintage of Cost Data and Timing of Measure Cost Review

The purpose of this guideline is to ensure measure costs reflect the current market and keep pace with market changes. The rate of market evolution and change is different for different technologies, and measure developers should reflect their understanding of the technology market in the cost analysis documentation. Essentially the measure developer and lead utility for the measure must consider if adjusting for inflation eliminates the "too old" issue, or if other market changes have occurred that necessitate an update.

This guideline defines three trigger points for measure cost review:

> **Cost review date.** The measure developer should propose a cost review date at which point measure costs should be reviewed and (potentially) updated. The cost review date should be based upon their understanding of the market, historical trends, and anticipated pace of market change. The cost review date might be the "sunset" data at which time all aspects of the measure analysis and parameters should be reviewed and potentially updated. Costs, however, might change at a more rapid pace than other parameters and more frequent review might be warranted.
>
> **Data vintage.** Adjust measure costs for inflation if measure costs will not be updated but the vintage of cost data is more than two years old. Adjustment factors can be developed using the RSMeans price indices.
>
> **Other measure updates.** Measure costs should be reviewed and updated if baseline and/or measure offerings change, to ensure costs are aligned with base and measure case specification.

[29] Documentation requirements are also provided in the *Measure Development and QA/QC Guidelines*. The current version can be downloaded from the Cal TF website (http://www.caltf.org/tools).

Guideline 11: Define Data that Should be Collected During Implementation

The purpose of this guideline is to facilitate data collection during implementation that can support future measure cost updates and better understanding of equipment that is incentivized and installed through the California deemed portfolios. As noted in the WO017 report, "program tracking data has been under-leveraged as a raw data source for measure cost studies … Additionally, and perhaps most importantly, the IOUs' program tracking data do not include the individual make/model information for rebated products, which makes it impossible to directly and quickly assess the types of products purchased through programs …" (p. 5-16, 5-17) The WO017 report further notes that integrating equipment make/model information is a low-cost method that will support a variety of needs, including developing sales volume weights, measure cost updates, market share tracking, and market assessments. Installation costs, while not applicable or available for some rebated equipment, if incorporated into the rebate application and program tracking systems, could provide a richer dataset of installation costs and at a minimum could be used to validate secondary data sources that are currently used for the majority of measures.

The statewide measure characterization provides the "Data Collection Requirements" field for measure developers and/or PAs to specify what data should be collected during implementation that will ultimately support future measure updates. Examples include:

- Installation labor costs
- Make/model and cost of equipment
- Non-equipment costs
- Infrastructure costs (for fuel substitution measures, see Guideline 12)

Data collection requirements specific to measure cost could support measure cost validation, ensure that cost estimates accurately reflect actual prices paid (including contractor markups, volume discounts, etc.) and will help program developers and PA have a better understanding of the equipment incentivized and installed through programs.

Guideline 12: Document Infrastructure Costs During Implementation (Fuel substitution Measures Only)

Infrastructure costs for fuel substitution measures, such as electrical panel upgrades, should be estimated, even though they are currently not required to be included in the cost estimate as per; the *Fuel Substitution Technical Guidance for Energy Efficiency*.[30] Infrastructure costs should be recorded for each project during implementation to validate and refine future infrastructure cost estimates.

[30] The *Fuel Substitution Technical Guidance for Energy Efficiency* (version 1.1) states: "As directed in Decision 19-08-009, the measure technology cost may exclude any additional upgrades required to increase the building's total electric or natural gas load (e.g., electric panel upgrades, running new gas lines, increasing size of natural gas lines, etc.). If additional upgrades are included in the measure technology cost, cost assumptions should be included in workpapers or project submittals, with appropriate justification and rationale. The necessity of such building upgrades is specific to individual buildings and the cumulative total of installed technologies in the building, and therefore, in most cases, should not be attributed entirely to a single measure technology." (p.10)

Other Recommendations

Recommendation 1: Conduct and/or Leverage Targeted Market Assessments

In the WO017 report Itron recommended that regular, targeted market assessments be conducted to determine if market changes have occurred that warrant a formal cost update. The recommendation is worth repeating here because of the value of periodic market studies to keep the pulse of market trends that would trigger the need for a cost update, but also because of the value of such research for the portfolios in general. Indeed, periodic targeted market assessments are often recommended by evaluation studies and can be designed to fulfill a variety of research needs including (but not limited to): industry standard practices, market effects indicators, product mix/availability, and emergent market trends and disruptive technologies. As Itron points out, periodic market assessments can be designed to collect data on product attributes and market share data that is needed for hedonic price models and weighting factors for other methods. Conducting such data collection and research in a coordinated and focused manner on a regular cadence will help to maintain measure costs more effectively and efficiently. Such studies can also be used to benchmark costs to assess the validity of resultant cost estimates. Finally, if market assessments can be scoped and budgeted on a longer-term timeline to enable study repetition, additional value can be gained from economies of scale.

Recommendation 2: Synchronize Measure Cost Reviews and Updates on a Regular Basis for Groups of Measures to Leverage Economies of Scale and Potential Cost Sharing Opportunities

As noted above, one challenge with the legacy IOU workpaper system is not only that deemed measures were developed separately by the IOUs, but also that the DEER "ecosystem" does not enable an efficient review of parameters, data sources, and analytical methods across multiple measures at the same time. Doing so is now possible with the eTRM and will become even more efficient with increased reporting capabilities that will be added in 2021.

The value of reviewing costs – not just the values but the data sources, data vintage, and analytical methods, as well – on a regular basis (say, every two years) is to determine if costs reflect current market conditions and if updates are needed. (And using more frequent market assessments as per recommendation #1.) The value of reviewing costs for groups of measures at the same time is to increase efficiency and leverage data sources that might be applicable for multiple measures and other economies of scale.

Such coordination will be particularly important with the absence of a comprehensive measure cost update study; PAs and 3Ps will not have the benefit of leveraging a cost study and will be responsible for developing measure costs on their own, which could potentially lead to inconsistencies and duplication of effort.

Recommendation 3: Integrate Data Needs into eTRM to Support Measure Update Planning and EM&V

Currently, measure updates are determined on measure-by-measure basis, but it is generally agreed that planning for updates would greatly improve value (though prioritization) and reduce the cost (by leveling workload). Data that could be tracked in the eTRM in the future to quantify the strength of cost data and resultant estimates that would help to prioritize and levelized workload include:

- Number of cost data points per measure or per offering
- Average and standard deviation of the estimated cost of each offering
- Claims data with the quantity of each measure offering that was installed (used for weighting purposes)
- Vintage of cost data
- Indicator if data was adjusted for inflation and year of converted cost data
- Data source type (primary is preferred, or secondary)
- Data source description
- Cost calculation method (simple average, weighted average, regression analysis/hedonic model, etc.)
- Metric to understand cost volatility of measure or use category
- Categorization of who rebates are paid to (distributor, contractor versus end customer)

Inputs like these could inform the methodology that should be used for future updates and for similar measures. High impact measures should be thoroughly documented, and lower impact measures can be appropriately prioritized to improve documentation over time.