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2010-2012 WO017
Ex Ante Measure Cost Study
Final Report

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ES

Executive Summary

This report presents the results and findings from Work Order 17 – the Ex Ante Measure Cost Study. The primary objective of the study is to provide the California Public Utilities Commission (CPUC) and the Investor Owned Utilities (IOUs) with improved ex ante measure cost estimates to support fulfillment of CPUC policy requirements.

The scope of this study initially included all deemed measures contained in the Database for Energy Efficient Resources (DEER), as well as non-DEER deemed measures. This scope was distinctly different from those in previous measure cost studies conducted in California, which have been strictly limited to DEER measures. Given the diversity of deemed measures in the IOU portfolios and their differing overall importance in total portfolio-level expenditures and impacts, the study team developed a ranking methodology to identify the highest priority deemed measures for which to develop updated measure cost estimates. These rankings were based on measure-specific assessments of three specific criteria: the overall quality of the current DEER or IOU workpaper measure cost estimate; the expected contributions to total 2013-2014 portfolio incentive expenditures, and the expected magnitude of interactions with future revisions to building codes, appliance standards, and labeling programs. After examining the relative priority rankings produced with this methodology and soliciting feedback from the IOUs, Commission staff determined the final scope of the study, which included 63 measure groups and over 100 unique technologies.

Before developing measure-specific data collection strategies for in-scope measures, the study team developed a set of specific research objectives that built directly upon the detailed review and assessment of the data sources and methods underlying the current set of incremental cost estimates in DEER and the IOU workpapers. These specific objectives were:

- Use substantially larger sample sizes from highly representative sample frames
- Increase use and improve specification of regression-based cost models
- Use systematic, independent validation of results
- Incorporate anticipated interactions with future codes, standards, and labeling programs
- Develop additional lifecycle cost data
- Streamline data acquisition and development for future updates

To develop estimates of the average retail unit price for in-scope deemed measures, the study team used two general approaches to data collection and development. For mass market measures that are primarily sold directly to final consumers through retail channels, the study team collected and developed large samples of actual retail price observations at the point of sale from two primary sources: 1) large point-of-sale (POS) datasets acquired from third-party marketing firms, and 2) a large sample of in-store retail price observations (also known as retail shelf surveys). Collecting and developing such samples allowed incremental costs due to efficiency to be estimated using regression-based cost modeling (also known as hedonic price modeling).

For measures that are procured and sold to consumers primarily or exclusively via contractors, the study team used a "retail price build-up" approach where unit price data was collected at the distributor level and supplemented by explicit estimation of bulk purchase discounts, contractor mark-ups, warranties, and other factors that determine the average retail price faced by final consumers. This approach closely mirrors the equipment and project pricing practices used by contractors, energy service companies, and program implementers who procure and install energy efficiency measures on behalf of customers. Through a Request for Qualifications process conducted explicitly for this study, Itron identified five firms that regularly specify, procure, and install energy efficiency technologies on behalf of customers and have established relationships with the relevant equipment distributors in California. These firms then solicited equipment price lists from distributors on behalf of the study team.

Upon assembling and cleaning the equipment price datasets, the study team then developed and tested hedonic price models. This method is a statistical approach to isolating and estimating the relative influence of various individual product features on the product's final, observed price. In the case of this study, the key product feature of interest is usually the energy performance of the equipment as measured by metrics such as the Seasonal Energy Efficiency Ratio for air conditioners or the annual unit energy consumption for refrigerators. Hedonic price modeling has many attributes that make it highly appealing for incremental cost estimation. First and foremost, it allows incremental cost estimates to be explicitly controlled for cost-influencing factors that are not related to efficiency performance. Second, it allows incremental costs to be estimated across a continuum of technology specifications and can be applied to both program-level and measure-level planning activities. Third, it allows for the explicit quantification of the uncertainty associated with the result for each independent variable.

It should be noted that for a significant subset (roughly one quarter) of in-scope measures, it proved difficult, inappropriate, or unnecessary to estimate incremental cost using hedonic modeling. In these cases, the study team used built-up costs developed by specialized subcontractors or simple averaging (either on a matched pair basis or whole-sample basis).

Apart from unit equipment prices, non-equipment installation costs (e.g. labor) are also needed to estimate the incremental costs of all add-on measures, early replacement measures, and replace-on-burnout measures that involve "cross-technology" baselines (e.g. tankless water heaters replacing storage water heaters). To develop estimates of non-equipment installation costs, the study team used three general approaches. For most linear fluorescent lighting and split/packaged air conditioning measures, the study team used estimates of installation labor hours developed from a large sample telephone survey of contractors, conducted jointly with other related evaluation studies. For other nonresidential heating, ventilation, air conditioning, building shell, and lighting measures, the study team developed a large set of artificial project bids and solicited itemized price quotes from multiple specialized contractors. The artificial bids were designed to identify and develop cost estimates for the major variations in site conditions that have the most influence on total project costs (e.g. basement versus roof locations). For all other measures, the study team used installation cost estimates from secondary sources such as RSMeans and the Technical Support Documents developed and published by the U.S. Department of Energy.

A critical step in the study team's overall analysis approach was to systematically validate and benchmark the team's estimates of average equipment prices and installation costs wherever possible. For certain technologies, the study team was able to access large sets of "out of sample" price data to use for this model validation step (e.g. the complete set of customer invoices from the California Energy Commission's Cash-for-Appliances program). For most technologies, however, the amount of "out of sample" price data readily available for this validation step was more limited. In these cases, the study team developed necessarily smaller validation data sets based on web-based price lookups from online retailers or distributors and/or contractor price quotes from artificial project bids developed by the study team. For large capital equipment (e.g. chillers, boilers, packaged heat pumps, etc), there were typically no "out of sample" price data readily available from web-based price lookups. In these cases, the study team used a combination of artificial project bids, previous DEER estimates, IOU workpaper estimates, and average unit prices from RSMeans for the validation exercise. Similarly for installation labor hours, the "out of sample" data readily available to the study team typically consisted of some combination of artificial project bids, previous DEER estimates, IOU workpaper estimates, and average labor hours from RSMeans.

In total, the study team developed hedonic price models for 75 technologies, built-up equipment price estimates for 24 technologies, and simple average price estimates for 17 technologies. The study team also developed non-equipment installation cost estimates for 85 technologies. These estimates were then used to develop incremental measure cost estimates for well over 600 specific deemed measures currently defined in the most recent version (1.0.4) of the Remote Ex Ante Database Interface.

Finally, the study team developed two sets of specific recommendations for future work: one set focused on technology-specific research recommendations and one set focused on specific methodological and process-related recommendations for future measure cost studies in California. The technology-specific recommendations – which were designed to be more topical in nature, rather than related to overall research design, data collection, or analysis approaches – were developed from particular issues that were identified through the course of the study but could not be resolved or addressed within the scope of the project. These recommendations are:

- Further explore how installation costs scale with increasing capacities for large capital equipment
- Perform dedicated research on network power management software
- Incorporate Luminaire Efficiency Rating into the incremental cost analysis of nonresidential lighting fixtures

The methodological and process-related recommendations attempt to build upon the methodological and data collection advances made in this study and address the main challenges faced by the study team. These recommendations are:

- Perform regular, targeted market assessments to inform cost data collection
- Integrate make/model and installation cost data into program tracking for downstream deemed measures
- Consider standardizing data development and analysis procedures for measure cost estimation

For the latter recommendation, the study team recommended four specific strategies to standardize the data development and analysis procedures for measure cost studies going forward:

- Continue the use of hedonic price modeling as the primary analytic framework
- Systematic use of product compliance databases
- Expanded and regular use of POS data
- Expanded and consistent use of artificial project bids

1

Introduction

As part of the portfolio of 2010-2012 EM&V activities, the Database for Energy Efficient Resources (DEER) and the ex ante values contained therein are being updated with the best and latest information available. In the case of measure costs, these updates (and the associated research and data development) were conducted through a stand-alone Measure Cost Study (MCS) and, where efficient, necessary, and appropriate, through cost-related data collection and research conducted as part of other EM&V studies (e.g., impact evaluations, process evaluations, and market studies). Together, the MCS and related EM&V studies provide the California Public Utilities Commission (CPUC) and the Investor Owned Utilities (IOUs) with improved measure cost estimates to support fulfillment of CPUC policy requirements.

This work was conducted under the direction of the CPUC staff with input from the Commission's DEER and energy efficiency cost-effectiveness teams. Itron, Inc. served as the Prime Contractor managing this study, lead by Mr. Mike Ting. The CPUC Project Manager for this study was Ms. Katie Wu. The following is Mr. Ting's contact information:

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1.1 Regulatory Use of Ex Ante Measure Costs

Ex ante values are energy efficiency impact and cost estimates developed prior to or during implementation of programs and prior to installation of the measures by end users. Ex post values are estimates of savings that are informed by observation and measurement of savings or factors related to savings that occur after energy efficiency measures have been implemented. CPUC policy requires the California IOUs to file ex ante estimates of the expected per-unit costs and savings for each measure included in proposed energy efficiency programs for each program cycle. The CPUC uses these values to assess the overall portfolio cost-effectiveness. The IOUs also use these values to track program accomplishments against annual savings goals.[1,2] Additionally, ex ante savings values have been used in the determination of the level of rewards the IOUs can receive for successful energy efficiency efforts.[3]

For deemed measures contained in the CPUC-managed DEER, the IOUs are required to use the corresponding ex ante values from DEER or present specific justification for diverging from DEER values. For deemed measures not contained in DEER, the IOUs must submit workpapers that estimate and justify proposed ex ante values for each non-DEER measure. These workpapers are reviewed and approved by ED before the corresponding ex ante values can be applied to assess cost-effectiveness or to track and report accomplishments.

1.2 Scope and Objectives of MCS Update

The primary objective of this MCS update is to develop ex ante measure cost estimates for measures supported by IOU programs in the current program cycle and likely to be supported by IOU programs in the next program cycle. The scope of this MCS update therefore initially included all deemed measures contained in the DEER database, as well as non-DEER deemed measures and custom measures supported by “calculated” incentive programs. This scope was distinctly different from those in previous measure cost studies conducted in California, which have been strictly limited to DEER measures.

Importantly, because the scope of this study includes non-DEER measures, the MCS update focused not only on developing ex ante measure cost *values* but also on developing the methods, tools, and data sources to support standardized estimation of ex ante measure costs for non-DEER and calculated incentive measures.

This report presents the data, methods, and results used to estimate ex ante measure costs for in-scope deemed measures. The work products associated with the cost research conducted for calculated incentive measures will be reported separately.

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1 For a detailed overview and discussion of current CPUC policy related to the use of ex ante estimates, see *Decision Approving 2010 to 2012 Energy Efficiency Portfolios and Budgets,* D.09-09-047 (September 24, 2009) and *Third Decision Addressing Petition for Modification of Decision 09-09-047*, D.11-07-030 (July 22, 2011).

2 Currently, the two primary cost-effectiveness tests used to inform energy efficiency policy making (including goal setting, portfolio cost-effectiveness requirements, and the risk-reward incentive mechanism) are the total resource cost test (TRC) and the program administrator test (PAC). The TRC test requires program costs, incentive costs, and participant costs. Program costs and incentive costs are the two principal cost elements for the PAC test.

3 See Section VIII (Performance-Based Risk and Reward Incentive Mechanism) of the Energy Efficiency Policy Manual, version 4.0 available at: http://www.cpuc.ca.gov/NR/rdonlyres/FCE88E10-C186-479F-BFFF-CB722750B1AA/0/CPUCEnergyEfficiencyPolicyManual.doc. Note, however, that the CPUC is currently soliciting comments from parties on the design of future risk/reward mechanisms, including the use of ex ante values, in Rulemaking 09-01-019.

Costs vs. Prices, Measures vs. Technologies, Measure Costs vs. Incremental Measure Costs

Note that the term "cost" will be used in this study, as it was in previous measure cost studies due to common usage of this term in cost-benefit applications. Technically, however, the study deliverables are estimates of the *prices paid by customers* for energy-efficient products and services. This distinction is important because, in the economics and business literature, the term "cost" usually refers to production costs and/or opportunity costs borne by businesses when *producing* a particular good or service.[4]

Similarly, the term "measure" will be used throughout this study to refer to interventions that increase the efficiency performance of an energy-consuming system. In practice, energy efficiency measures are often the replacement of one *technology* for another (e.g. compact fluorescent lamps replacing incandescent lamps). Robust incremental cost accounting thus requires developing prices and cost streams for both high-efficiency technologies and their in-situ or standard-efficiency counterparts. In this respect, the primary focus of this research is estimating prices and cost streams for both high-efficiency technologies and their in-situ or standard-efficiency counterparts, from which incremental measure costs can then be estimated under a variety of different implementation contexts (e.g. early replacement, replace-on-burnout, etc).

Finally, the term "measure costs" will be used generically throughout this study. Strictly speaking, however, what determines the cost-effectiveness of measures and programs to society (as represented in the TRC test) and what program administrators typically use to set incentive levels is the *incremental* cost of energy efficiency measures, i.e. the additional cost associated with adopting a high-efficiency technology compared to a standard- or average-efficiency technology. Depending on the type of measure, the incremental measure cost may in fact be the full measure cost (e.g. for add-on measures like pipe insulation), the difference in costs between a base technology and replacement technology at two different points in time (e.g., early replacement), or it may be the difference between the full measure cost and the cost of the standard-efficiency counterpart (e.g. for replace-on-burnout measures like SEER 15 central air conditioners). In this study, the Itron team developed both full measure costs and incremental measure costs, and we use the umbrella term "measure costs" to generically refer to both.

4 See, for example, the definition of "cost" offered at: http://en.wikipedia.org/wiki/Cost.

1.3 Roadmap to Report

The remainder of this report is organized as follows:

- **Section 2** provides an overview of the research and data collection approaches developed and implemented by the study team
- **Section 3** presents the final data sources and ex ante estimates of average unit equipment prices and incremental costs for each in-scope deemed measure and provides additional detail on technology-specific modeling issues, market assessment findings, and key findings
- **Section 4** presents the final data sources and ex ante estimates of non-equipment installation costs for all in-scope measures, where required to calculate incremental measure costs, and provides additional detail on technology-specific installation cost estimation issues and key findings
- **Section 5** discusses the overall results, key differences from previous ex ante measure cost estimates, key sources of uncertainty, lessons learned, and recommendations for future work

2

Research Approach and Methodology

This section provides an overview of the research approach developed and implemented by the study team in order to complete the study scope and objectives described in Section 1.

Due to the breadth and scope of the energy efficiency measures contained in the IOU program portfolios, it was unreasonable for the study team to attempt to specify *a priori* the exact data sources and methods that would be used for each in-scope measure. Rather, the study team developed a research approach that produced a series of interim deliverables designed to allow measure-specific data collection and analysis plans to be developed and executed as the data sources and analytic options for each in-scope measure were identified and assessed. In this respect, the research plan developed by the study team (and approved by Commission staff) sought to lay out the overall process by which measure-specific data collection and analysis plans would be developed and implemented.[1]

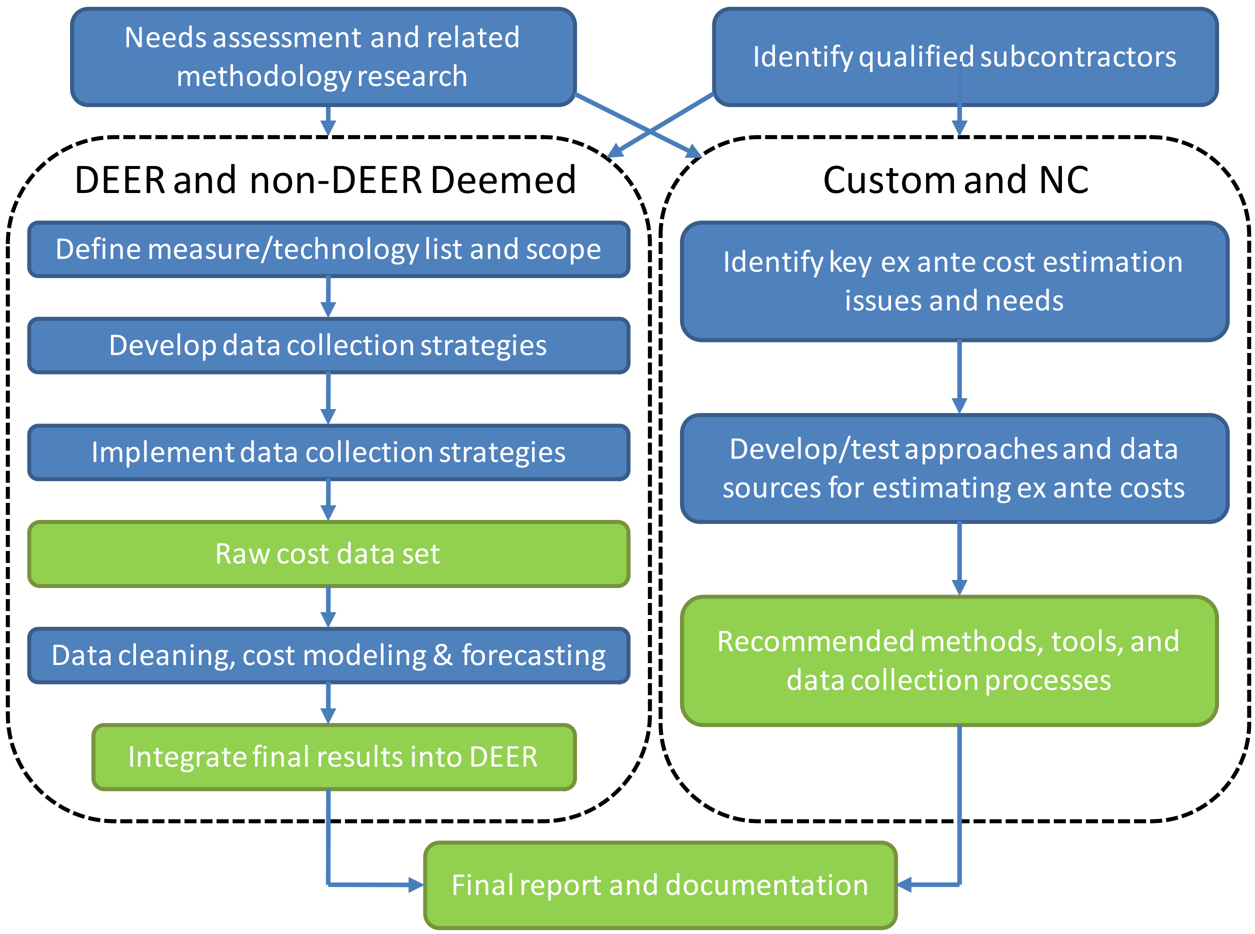
The overall MCS research was organized into two parallel tracks: deemed measure cost research and development (including both DEER and non-DEER deemed measures) and calculated measures cost research and development (i.e. custom retrofits and new construction). Importantly, however, these two parallel tracks were rooted in a common starting point – namely a Request for Qualifications (RFQ) process to identify qualified subcontractors and a needs assessment to identify the highest priority regulatory and program planning needs of the CPUC and its stakeholders. Upon completion of the RFQ process and the needs assessment, the deemed measure cost research was organized into the following major tasks:

- Define measure list and scope
- Develop data collection strategies
- Implement data collection strategies
- Conduct data cleaning, cost modeling, and analysis
- Integrate cost results into DEER

1 The final approved MCS research plan is available at: http://www.energydataweb.com/cpucFiles/56/WO017MeasureCostStudyResearchPlan_1.pdf

The overall MCS research approach and the relationships between major tasks are summarized below in Figure 2-1. In the subsections that follow, we summarize the specific research activities and key findings from each of the deemed measure research tasks, along with links to the associated milestone deliverables.[2] The final set of measure-specific data sources, models, and results are presented separately in Section 3, and the discussion of the DEER integration task is presented in Section 4.

Figure 2-1: Flowchart of Overall MCS Research Approach and Tasks



2.1 Request for Qualifications

Given the breadth and scope of the measures in the IOU program portfolios, neither Itron nor DNV-GL (the two co-prime contractors for the CPUC's portfolio of 2010-2012 EM&V studies) have all of the required technology-specific expertise to cost-effectively develop robust incremental cost estimates for all measures in the scope of the MCS. As such, Itron developed a

[2] As noted earlier in Section 1, the research and results for *calculated* incentive measures will be delivered in a separate report and are not presented here.

Request for Qualifications (RFQ) that was strategically designed to identify qualified subcontractors that can readily provide the raw measure cost data required for this study and/or have demonstrated experience in related measure cost data development and analysis.[3]

Itron released the RFQ on September 19, 2011, which results in 15 firms submitting formal responses and qualifications. In the latter half of October and November, Itron reviewed all of the submitted qualifications and mapped those qualifications to the technology scope of WO17 and the areas of greatest need. Itron then conducted follow-up interviews with responding firms and, in several cases, requested additional materials to support claimed qualifications and areas of expertise (e.g. example work products).

Having mapped each subcontractor's qualifications against the technology-specific needs of the MCS and Itron's own data collection, analysis, and management capabilities, Itron then proposed specific project roles and scopes for seven different subcontractors, which were approved by Commission staff. The resulting composition of the MCS subcontractor team is summarized in Table 2-1 below.

Table 2-1: Subcontractor Roles and Scopes for MCS

MCS Measure Group(s)	Subcontractor(s)	Scope/Role
Residential Appliances/Electronics	NPD Group	Data purchase*
Residential Lighting	DNV-GL**	Turnkey
Residential HVAC/Shell/WH	Davis Energy Group (DEG)***	Data development and analytic support
Nonresidential Lighting		
Nonresidential HVAC/Shell/WH	TRC Energy Services**** Quantum Energy Services & Technologies (QuEST)	
Commercial Food Service	Energy & Resource Solutions (ERS)	
Commercial Refrigeration	VACOM Technologies	Turnkey

* Purchase-order type engagement only. No contract-for-services arrangements required.
** DNV-GL's budget was authorized via a separate, shadow work order for WO17, so their operating budget did not impact any of the budget allocations developed by Itron as part of the subcontractor engagement process.
*** Via their subsidiary, Advanced Energy Products.
**** Formerly EMCOR Energy Services.

As Table 2-1 shows, for the bulk of the MCS subcontractor engagements, the subcontractor roles were limited to data collection, development, and analytic support. In these cases, Itron staff performed the lead role in developing technology-specific data collection plans and producing the final incremental measure cost estimates. In certain cases, Itron's lead staff solicited

3 The final RFQ is available at: http://eega.cpuc.ca.gov/Docs/REQUEST%20FOR%20QUALIFICATIONS%20-%20Final_9.19.11.docx

input/feedback from specific subcontractors on Itron's proposed analysis approaches and work-in-progress estimates full and incremental measure cost estimates.

Note that for residential lighting and commercial refrigeration measures, the subcontractor roles were more expansive, turnkey engagements, with the respective firms being responsible for developing and implementing data collection plans, developing full and incremental measure cost estimates for all in-scope measures, and providing complete documentation and reporting (subject to review and approval by Itron and Commission staff). In the case of residential lighting, DNV-GL was well-positioned to leverage data collection and analysis activities scoped and initiated as part of WO28 (residential lighting impact evaluation) and WO13 (residential lighting market characterization). In the case of commercial refrigeration, Itron recommended a turnkey engagement with VACOM due to the highly-specialized engineering expertise, market knowledge, and market relationships required to collect, develop, and analyze costs for those technologies and measures.

2.2 Needs Assessment

Following the RFQ process, Itron conducted a needs assessment among staff from Energy Division, the IOUs, and other stakeholders. The needs assessment was designed to explicitly identify the regulatory and program planning needs of the CPUC and its stakeholders related to ex ante measure costs, both currently and going forward. The results were then used to help frame the corresponding expectations for the MCS to ensure that its outputs align, to the extent possible, with the highest priority needs.

To conduct the needs assessment, Itron developed a written questionnaire that allowed participants to identify, describe, and rank their respective needs related to ex ante measure costs. The questionnaire was designed to solicit perspectives related to specific ex ante measure cost data needs including, but not limited to, the following:

- The need for ex ante measure cost values to support backwards-looking applications like cost-effectiveness versus forward-looking applications like program planning, filings, reporting
- The need for ex ante measure cost needs at the tracking level (e.g. SPT) versus the planning level (e.g. DEER or even greater levels of measure aggregation)
- The need for ex ante measure costs for deemed measures versus custom measures
- The need for ex ante measure cost values to support net present value and lifecycle cost analyses
- The need for ex ante measure cost values to support refinement of the inputs to and requirements of the TRC and PAC tests

- The need for ex ante measure costs that include a portion of program costs (e.g. for direct install measures)?

The questionnaire was sent to key staff from Commission staff, the IOUs, and other stakeholders on September 11, 2012. On October 1, 2012, Commission staff hosted a meeting at the CPUC to discuss the responses to the questionnaire. Representatives from each of the four IOUs as well as staff from Commission staff, Itron, and Itron's subcontractors attended the meeting either in person or via phone. Although the IOUs and stakeholder's perspective on various needs related to ex ante measure costs differed on several fronts, there were eight areas of consensus or near-consensus among the IOUs that emerged from the questionnaire responses and resulting group discussion:

- The IOUs use point estimates of ex ante measure costs for program design and planning, cost-effectiveness, and CPUC reporting[4]
- The IOUs did not express a significant need for measure costs customized or disaggregated by market segment (e.g., by building/customer type) but did express a need for MCs that cover a wider range of more granular technology definitions that are closer to the products actually available in the market and supported by programs
- The IOUs expressed a clear and significant need for regular, 3-year updates to ex ante MCs in sync with program planning schedules[5]
- The IOUs expressed a need for guidelines and protocols for developing ex ante measure costs for non-DEER deemed measures to integrate into their respective work paper processes[6]
- The IOUs expressed a need for guidelines and protocols for developing ex ante measure costs for custom/new construction measures to integrate into their project application, tracking, and evaluation processes[7]

[4] For negotiating contracts with third party implementers and direct install contractors, SoCalGas noted that they would like to have ranges of full and incremental measure costs available to help them "get the best deal." In other words, having ranges of full and incremental measure costs allows the IOUs to be able to account for the magnitude of bulk purchasing discounts and other procurement advantages that contractors have access to when negotiating turnkey contracts.

[5] The IOUs also expressed a need to at least track annual changes in measure costs for a specific subset of measures: high-impact measures , measures experiencing significant price changes (e.g., consumer electronics), and measures targeted by market transformation and codes and standards advocacy programs. This annual tracking activity for select measures would not be linked to mid-cycle updates of ex ante values but rather provide timely, strategic information to respective program managers. Additionally, such an activity would provide the time series information necessary to evaluate market transformation, conduct market effects studies, and assess progress towards the cost-effectiveness metrics required by the California Energy Commission for integrating technologies and measures into Title 20 and Title 24.

[6] This need stems from the frequently changing nature of each IOUs list of high-impact measures and the lack of corresponding ex ante measure cost values in DEER (currently).

- The IOUs expressed a desire to have lifecycle cost data made available to better assess cost-effectiveness, at least for certain measures
- The IOUs expressed a need for guidelines and protocols on using measure costs and related data for lifecycle cost analysis
- The IOUs expressed a need for guidelines and protocols for forecasting measure costs

The five of the first six consensus needs listed above were largely consistent with the original objectives, scope, and authorized budget of the MCS – the sole exception being the need for guidelines and protocols for developing ex ante measure costs for non-DEER deemed measures. The latter two consensus needs were not within the original scope of the MCS (protocols for using measure costs and related data in life-cycle cost analysis and protocols for forecasting measure costs), and indeed proved infeasible to add to the project scope given other competing priorities. Additionally, the consensus need related to protocols for using measure costs and related data in life-cycle cost analysis was determined to be more appropriately addressed in the energy efficiency proceeding and/or in the context of the E3 calculator. In this particular case, Commission staff urged the IOUs to initiate discussion of this issue in the context of those fora.

2.3 Define Measure List and Scope

In order to cost-effectively develop and implement data collection plans to support such a broad update to ex ante measure costs, the first step was to identify the "universe" of unique deemed measures currently being offered by the California IOUs. Once all the unique measures were identified, the next step was to classify and categorize these measures into groups for which generalized data collection plans could be appropriately developed and implemented. Given the breadth and scope of deemed measures in the IOU portfolios and their differing overall importance in total portfolio-level expenditures and impacts, the final step was to develop criteria and a process by which financial and analytic resources could be effectively allocated to ensure that incremental cost estimates for the highest priority measures were developed in an appropriately robust and timely way.

In the subsections that follow, we present and describe the approaches used to conduct each step of the overall measure list development and scoping process.

2.3.1 Measure List Development Approach

Given the inclusion of non-DEER deemed measures in the scope of the MCS, the first task was to identify all deemed measures in the IOU portfolios. Our approach was to start with the

[7] This need stems from the heterogeneity of custom measures and a lack of corresponding ex ante values in DEER, the difficulty of getting disaggregated project costs from project invoices, and a belief that current ex ante measure cost estimates used in custom and new construction projects are too high.

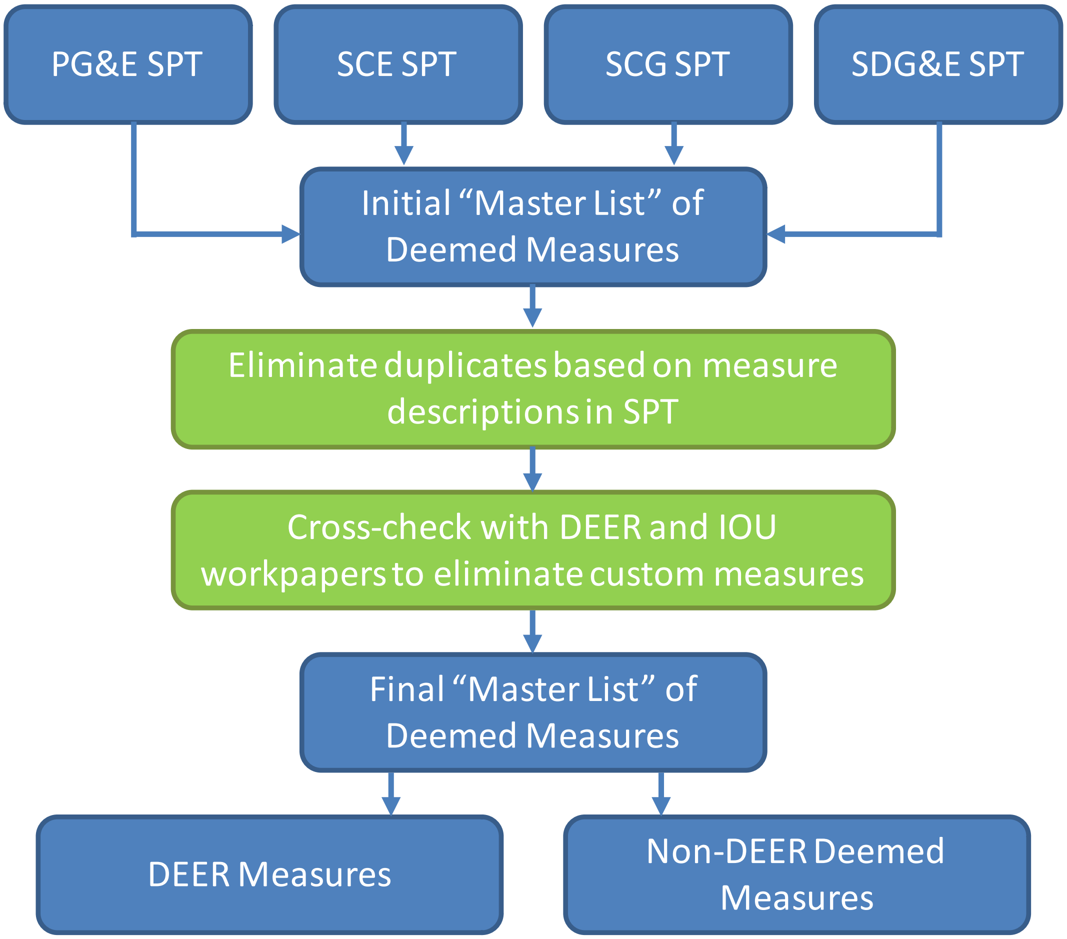
Standard Program Tracking (SPT) databases maintained by the IOUs (and provided to Commission staff, Itron, and DNV-GL to facilitate EM&V activities) and use the measure-specific program participation data in the SPT as the starting point for identifying unique deemed measures in the IOU program portfolios.

We leveraged the "deemed" flag in the SPT databases to develop an initial master list of all measures for which deemed incentives had been issued by the IOUs through the third quarter of 2011. Since many of the deemed measures in the SPT databases are identical across the IOUs, we then eliminated duplicate measures based on the measure descriptions. While care was taken to identify truly unique measures, the nomenclature in the IOU tracking databases is sometimes ambiguous. In an effort to maintain a comprehensive list of measures, some measures identified as "unique" may overlap in reality.[8] We then carefully cross-checked the resulting "de-duped" list of measures with the measures currently included in DEER and the IOUs' ex ante workpapers to identify and eliminate measures that were erroneously flagged as "deemed" measures in the SPT but were clearly custom measures.[9] Finally, we classified all remaining measures as either DEER or non-DEER deemed. This approach is summarized below in Figure 2-2.

8 For instance, in their tracking databases, SCE identifies the measure Medium Temperature Reach-in Display Case Door Gasket and SDGE identifies the measure Refrigeration Door Gaskets on Reach-in Doors. These may be identical measures and have identical costs, but for the sake of defining a comprehensive list, these are designated as two unique measures.

9 Examples of such cases include residential new construction projects and retro-commissioning. These measures are supported strictly by calculated incentive programs and are thus erroneously flagged as deemed measures in the SPT.

Figure 2-2: Overview of Measure List Development Approach



It is important to note that Itron initially used only the 2010-2012 SPT database to develop the "universe" of unique deemed measures. However, when the IOUs' respective 2013-2014 portfolio applications became available in July 2012, Itron also cross-checked the working "master list" of deemed measures with the measure information available in the IOU filings to ensure any deemed measures added to portfolios as part of the 2013-2014 cycle were included.

2.3.2 Measure Groups and Characteristics

The resulting "master list" deemed measures includes a wide array of both unique technologies and combinations of unique technologies. In order to cost-effectively develop and implement data collection plans to support such a broad update to ex ante measure costs, the next step was to classify and categorize these measures into smaller and more manageable sets of "measure groups" for which common data collection plans could be developed and implemented.

For example, consider a measure consisting of a linear fluorescent lighting fixture with four 48" T12 lamps using magnetic ballasts being replaced with a 2-lamp fixture with two 46" T5 high-output lamps using electronic ballasts. The specific components of the baseline fixture and the high-efficiency replacement can be procured individually and fall in the following "measure groups": 1) fixtures (available in 1-lamp, 2-lamp, 4-lamp, etc. and varying lengths of 48", 96", etc.), 2) linear fluorescent lamps (i.e. T12, T8, T5, T5HO, etc. and varying lengths of 46", 48", 96", etc.), and 3) ballasts (i.e. magnetic and various types of electronic versions such as instant start, programmed start, etc.). Each measure group therefore comprises a set of technologies for which the same data development approach will apply, including the sources of unit price and installation labor data used, the data verification and validation steps applied, and the analysis approach used to estimate incremental measure costs.[10]

For each measure group, we then identified the key technology characteristics that define all the individual measures within a given measure group. Specifically, this meant defining the technology-specific capacity units, ranges, and key measure-defining characteristics relevant to estimating incremental measure cost, including the current minimum energy performance criteria for technologies that are currently regulated by the US Department of Energy (USDOE) or by the California Energy Commission (CEC).

Importantly, it should be understood that the capacity units identified and defined by the study team were not always the same as the "savings units" listed in DEER. Rather, the capacity units defined by the study team summarize the key criteria typically used when equipment is sized and procured in the market. For example, the "savings units" for heat exchangers in DEER are defined as "1,000 square ft of building". However, heat exchangers are sized (and priced) according to their capacity in terms of cubic feet of airflow per minute (CFM). These capacity units were delineated by technology in order to begin identifying a clear path to consistently and meaningfully integrating the savings impacts values in DEER and IOU workpapers with the incremental cost values developed in the MCS update.

For the complete list of measure groups defined by the study team and the associated set of key technology characteristics, see Tables 2-1 and 2-2 in the final *Task 4 Report*.[11]

2.3.3 Prioritization Criteria and Scores

As noted earlier, given the scope of deemed measures in the IOU portfolios and their differing overall importance in total portfolio-level expenditures and impacts, it was critical to develop criteria and a process by which financial and analytic resources could be effectively allocated.

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[10] In general, we attempted to stay as consistent as possible with the "technology group" and "technology type" categories developed in the 2011 DEER update. To be clear, however, the measure groups developed for the MCS update were designed for cost data collection and analysis planning purposes only and do not imply that those in the current DEER database should change or that the output of the MCS update will not be able to be aligned with the technology/measure segmentation currently defined in DEER.

[11] http://www.energydataweb.com/cpucFiles/pdaDocs/872/Task%204%20memo_final%20with%20appendices.pdf

This allocation process was necessary to ensure that incremental cost estimates for the highest priority measures were developed in an appropriately robust and timely way.

In order to identify the highest priority deemed measures for this MCS update, we considered the following three criteria:

- The overall quality of the current DEER or IOU workpaper estimate
- The measure's expected contributions to total portfolio kWh, kW, and therm savings
- Interactions with future revisions to building codes, appliance standards, and labeling programs

While it is always possible to consider additional factors to such a prioritization exercise, we chose to develop the three criteria listed above for two main reasons. First, we believe that the three criteria listed above adequately account for the highest-order factors that are relevant for initial planning. Second, the three criteria listed above can be assessed comprehensively and systematically across all of the in-scope deemed measures. This second aspect is critical to avoid creating undue burden on the overall project timeline or resources.

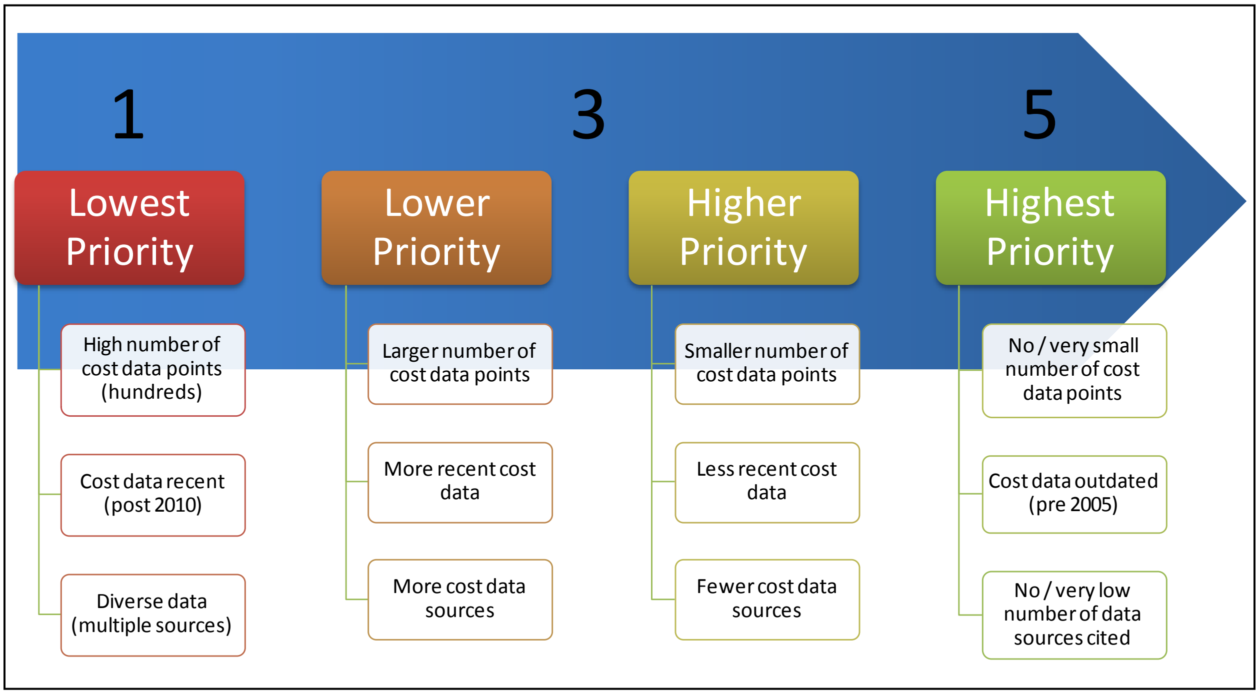
For each of the prioritization criteria, a score of 1-5 (low to high priority) was developed and assigned for each measure group based on all of the information compiled by the study team. The scores were then weighted across the criteria to calculate an aggregate score, and the measure groups were then ranked in descending order to identify the highest priority measure groups. Below we summarize the methodology and data sources used to develop the scores for each criterion.

<u>Quality of Current Estimate</u>

We assessed the overall quality of the current incremental cost estimates in DEER and the IOU workpapers in terms of the following factors: 1) sample size (number of raw cost data points), 2) vintage of the raw data (when it was originally collected), and 3) the diversity of the raw data sources (or use of other explicit data validation and quality control approaches). We then assigned a score of 1 to measures for which the current incremental cost estimate is high quality (and therefore lower priority for updating, all else equal). Conversely, we assigned a score of 5 to measures for which the current incremental cost estimate is low quality (and therefore higher priority for updating, all else equal).

For example, the current estimate of incremental measure cost for ENERGY STAR refrigerators in DEER is based on a large sample of 813 raw cost observations, composed of 286 observations from on-site retail shelf surveys and 527 price points observed in online product catalogues during the fall and winter 2007. For this exercise, the current incremental cost estimate for refrigerators is scored as a 1 (high quality, low priority for update). While the three factors listed above may interact in a number of ways to arrive at the same score, Figure 2-3 presents potential scenarios that are representative of each score. A detailed breakdown of the data sources and analysis methods used to support the current incremental cost estimates for deemed measures and their associated quality scores are presented by measure group in Appendix A of the final *Task 4 Report*.[12]

Figure 2-3: Quality of Current Estimate Scoring



<u>Current Portfolio Incentives Contribution</u>

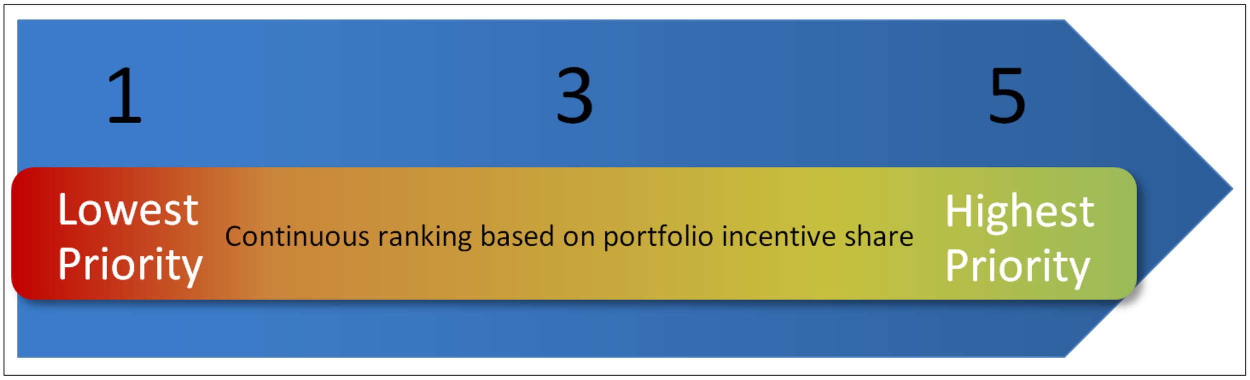
The second priority ranking criterion was designed to identify and prioritize measures that account for significant shares of total expected portfolio incentive expenditures and de-prioritize measures that account for very small or insignificant shares of total portfolio incentive expenditures. To do this, we leveraged the 2013-2014 IOU program application data to calculate aggregate incentive payments for each deemed measure group defined for this MCS update. We then calculated each measure group's relative contribution to total portfolio incentive payments by IOU in percentage terms.

For measures whose relative contribution to portfolio incentive expenditures was 1 percent or greater, we assigned a score of 5 (highest priority). Those with portfolio incentive contributions of <1-0.25% were assigned a score of 4, those with portfolio incentive contributions of <0.25-0.05% were assigned a score of 3, those with portfolio incentive contributions of <0.05-0.01%

[12] http://www.energydataweb.com/cpucFiles/pdaDocs/872/Task%204%20memo_final%20with%20appendices.pdf

were assigned a score of 2, and those portfolio incentive contributions of <0.01 percent were assigned a score of 1 (lowest priority).[13]

Figure 2-4: Portfolio Incentive Contribution Scoring

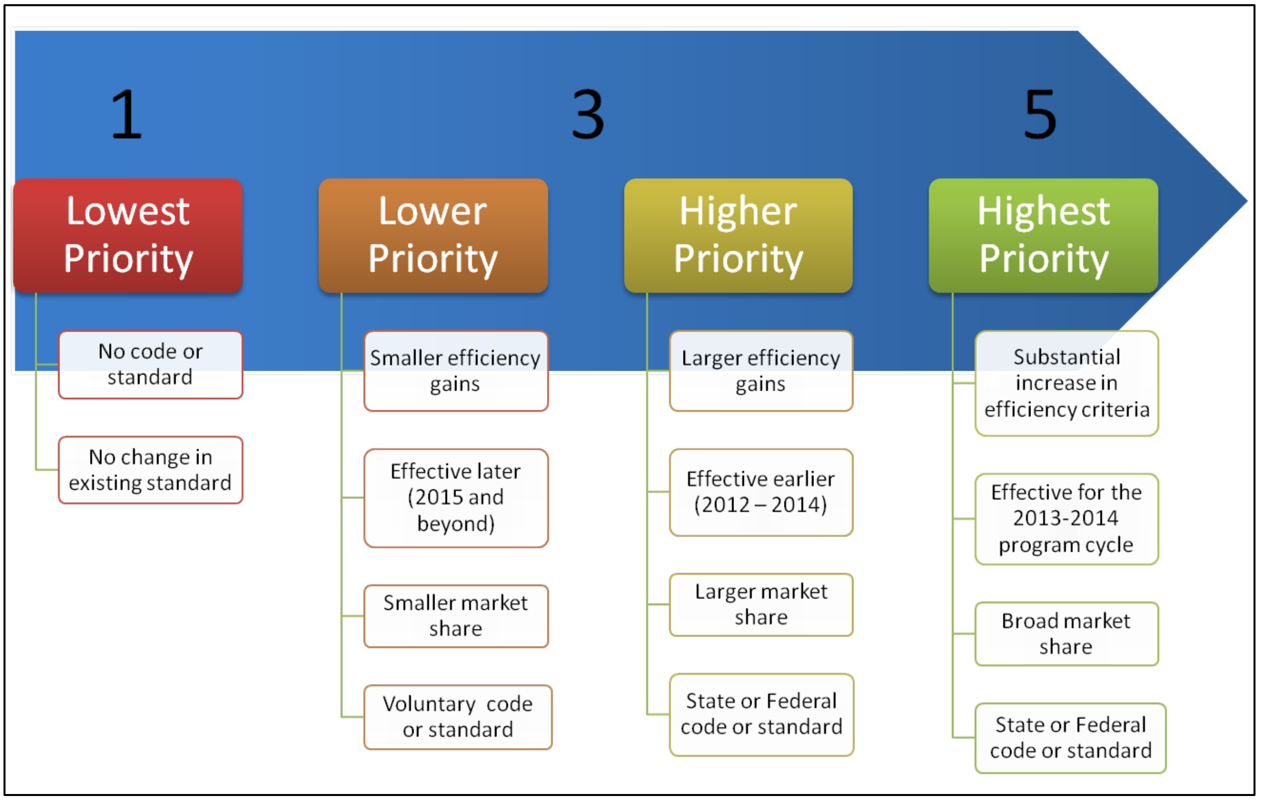


<u>Interactions with Future Codes, Standards, and Labeling Programs</u>

While it is difficult to establish a purely objective method of assigning priority scores for this criterion, three general factors contributed to the final score: 1) the degree to which the efficiency criteria are changing, 2) the specificity of the code or standard, and 3) the effective date of the code or standard. For instance, the Energy Independence and Security Act of 2007 requires efficiency gains of approximately 25 percent for general service incandescent lamps over the period 1/1/2012 to 1/1/2014. This regulation includes substantial efficiency gains in this program cycle and is applicable to a large number of products with broad market coverage. Thus, the impact of this standard on affected measures was assigned a priority ranking of 5. If another standard required similar efficiency gains but was highly specific to a niche technology and effective in late 2016, the score would be lower. While these three factors may interact in a number of ways to arrive at the same score, Figure 2-5 presents the general scenarios that are representative of each score.

13 The study team originally used contributions to portfolio energy and peak demand savings as the basis for this criterion. However, based upon feedback from Commission staff and the DEER team, this criterion was modified to use contributions to portfolio incentive expenditures. The resulting rankings were nearly identical to those using the original criterion. The exceptions were: 1) the higher ranking of network power management software, refrigerant charging and adjustment, storage water heaters, heat pump water heaters, indirect evaporative coolers, economizers, and reflective film; and 2) the lower ranking of anti-sweat heater controls, faucet aerators, building management system controls, and steam traps. The original set of "portfolio contribution" scores is available in Appendix B of the *Task 4 Report.*

Figure 2-5: Future Codes, Standards, & Labeling Scoring



The study team's assessments of interactions with future codes, standards, and labeling programs and the unit energy savings potential estimates used to synthesize the individual outlooks into priority scores were developed using publically available information from the USDOE, the California Energy Commission, and the USEPA.[14,15,16] The complete set of final scores for this criterion and detailed summaries of the specific proposed codes, standards, and labels assessed by the study team are provided in Appendix C and Appendix D of the *Task 4 Report*, respectively.[17]

2.3.4 Final Prioritization Rankings and Deemed Measure Scope

Based on the scoring and ranking methodologies summarized above, we then aggregated the priority scores across the three primary prioritization criteria to arrive at a final priority ranking for each in-scope measure group. In order to aggregate the scores, we developed weights for each of the prioritization criteria. In order to test the sensitivity of the overall priority rankings to

14 http://www1.eere.energy.gov/buildings/appliance_standards/

15 http://www.energy.ca.gov/appliances/2013rulemaking/index.html

16 http://www.energystar.gov/certified-products/certified-products?c=products.pr_find_es_products

17 http://www.energydataweb.com/cpucFiles/pdaDocs/872/Task%204%20memo_final%20with%20appendices.pdf

these weighting assumptions, we also developed two sets of alternative weighting values. The recommended weights, along with two sets of alternative weights, are shown in Table 4-1 of the *Task 4 Report*.

The weighted, aggregate priority ranking scores (and sensitivity cases) are shown in Table 4-2 of the *Task 4 Report*.[18] The study team then worked with the Commission staff project manager to examine the implications of using various cutoff points for determining the final scope for the deemed measure cost effort. Commission staff proposed using a 3.5 aggregate score as the cutoff value and solicited comments from the IOUs during the needs assessment roundtable meeting on October 1, 2012. After taking into account IOU feedback and strategic exceptions to the 3.5 cutoff score (e.g. LEDs and measures that fall under the Energy Upgrade California program umbrella), Commission staff issued a memorandum on October 11, 2012 that delineated the final scope for the deemed measure cost effort, which is included in Appendix A of this report. In total, the final scope included 63 measure groups and over 100 unique technologies.

2.4 Develop Data Collection Strategies

In this subsection, we present and describe each of the data collection plans and sources developed by the study team. We describe the strengths, limitations, and key analysis issues associated with each data collection strategy and identify the activities conducted by specialized subcontractors and those conducted by Itron staff. Note that the detailed documentation of the final set of individual data sources, sample sizes, and sample characteristics for each in-scope measure are provided in Sections 3 and 4.

It is important to note that the data collection strategies described below were designed to allow estimation of *both* full measure cost and incremental measure cost relative to either a code-defined baseline or a market average baseline. The proposed data collection activities for each measure group have been designed around the types of analysis we believe yields the most robust cost estimates based on factors such as delivery channel and the various cost-influencing factors associated with each in-scope deemed measure.

2.4.1 Data Collection and Analysis Objectives

Before developing measure-specific data collection strategies, the study team developed a set of specific research objectives that built directly upon the detailed review and assessment of the data sources and methods underlying the current set of incremental cost estimates in DEER and the IOU workpapers. These objectives were developed in order to explicitly identify aspects of data collection and analysis that should serve to increase the accuracy, relevance, and value of the updated ex ante incremental measure cost estimates for both the CPUC and IOUs. Given

18 http://www.energydataweb.com/cpucFiles/pdaDocs/872/Task%204%20memo_final%20with%20appendices.pdf

inevitable real-world constraints due to time and project resources, Commission staff and the study team acknowledged that it may not be possible to achieve all the objectives described below in a comprehensive manner. Nonetheless, it is important to identify and acknowledge the areas of data collection and analysis that both the current MCS update and future updates should strive to achieve. These specific objectives are:

- Use substantially larger sample sizes from highly representative sample frames
- Increase use and improve specification of regression-based cost models
- Use systematic, independent validation of results
- Incorporate anticipated interactions with future codes, standards, and labeling programs
- Develop additional lifecycle cost data
- Streamline data acquisition and development for future updates

The background and relevance of each of these objectives is discussed in detail in Section 3.3 of the Task 4 Report.[19]

2.4.2 Retail Unit Equipment Prices

To develop estimates of the average retail unit price for in-scope deemed measures, the study team used two general approaches to data collection and development. For mass market measures that are primarily sold directly to final consumers through retail channels, we collected and developed large samples of actual retail price observations at the point of sale. For measures that are procured and sold to consumers primarily or exclusively via contractors, we used a "retail price build-up" approach where unit price data is collected and analyzed at the wholesale or distributor level and supplemented by explicit estimation of bulk purchase discounts, contractor mark-ups, warranties, and other factors that determine the average retail price faced by final consumers.[20] These two data collection approaches, and the data sources associated with each, are described in more detail below.[21]

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[19] http://www.energydataweb.com/cpucFiles/pdaDocs/872/Task%204%20memo_final%20with%20appendices.pdf

[20] In support federal appliance standards rulemakings, the USDOE uses a "manufacturing cost" approach to estimate incremental costs due to efficiency improvements for mass market technologies. This approach involves isolating the specific equipment components that determine efficiency performance and using engineering analysis to estimate the incremental production costs of those components. This engineering analysis is then followed by a retail markup analysis to arrive at average retail price. This approach is well-developed and has proven to be acceptable to the USDOE's stakeholders but is also time and cost-intensive. In this respect, it is largely impractical and well beyond the resources of this study.

[21] Note that there are a few measures which are strictly services, and as such their incremental costs are entirely the labor costs associated with the service and do not include any retail technologies or materials. Specifically, the in-scope deemed measures that are strictly services are: refrigerator/freezer recycling, AC coil cleaning, and delamping.

Large Samples of Actual Retail Price Observations

For mass market measures that are primarily sold directly to final consumers through retail channels, we collected large samples of actual retail price observations at the point of sale. Collecting and developing such samples allowed incremental costs due to efficiency to be estimated using regression-based cost modeling (also known as hedonic price modeling). Regression-based cost modeling has many attributes that make it highly appealing for incremental cost estimation. First and foremost, it allows incremental cost estimates to be explicitly controlled for cost-influencing factors that are not related to efficiency performance. Second, these models allow incremental costs to be estimated across a continuum of technology specifications and are thus inherently flexible and applicable to both program-level and measure-level planning activities. Third, and perhaps most importantly, regression-based cost models allow for the explicit quantification of the uncertainty associated with the result for each independent variable, which is strictly not possible when using weighted or simple averages. In addition to the advantages provided by applying regression-based cost modeling to large samples of actual retail price observations, large samples of “point of sales” (POS) data for some measures can be readily purchased from third party marketing firms (e.g. ACNeilsen, Activant, NPD) which makes it possible to conduct regular, targeted updates for those measures. Indeed, large POS samples have been used as the primary datasets in nearly all of the Residential Market Share Tracking (RMST) studies sponsored by the CPUC and the IOUs since 2000.

There are several challenges associated with the approach of using large samples of actual retail price observations. The first of these challenges is that the price data must be recent enough to be relevant to the analysis, i.e. data collection is somewhat constrained to prices paid in the most recent 1-2 years. This is especially true for technologies that change rapidly, such as TVs and computer displays. Second, the use of large samples of actual retail prices often needs to be complemented by sales volume (or relative sale volume) data in order to properly account for any significant price differences observed across different retail channels. Finally, such data sets often need to be corrected for seasonal pricing (e.g. holiday sales), inflation, and changes in producer prices (e.g. for labor and commodities). The first two challenges described above are essentially additional data collection requirements. The last challenge described is primarily an analytic challenge for which econometric methods have already been developed and applied in a wide variety of contexts.

The study team identified several viable data sources that could be readily leveraged to develop large samples of actual retail price observations for specific measures, as well as a set of primary data collection activities that can be used to develop such samples and/or validate results. Table 2-2 shows the specific measure groups for which the study team recommends developing large samples of actual retail price observations and identifies the specific data sources and primary data collection activities recommended for each such measure group. The rationale for the study team's preference for the data sources shown in Table 2-2 is provided in Section 2.1.1 of the *Task 5 Report*.[22]

Table 2-2: Data Sources and Primary Data Collection Activities Used to Support Development of Large Samples of Actual Retail Price Observations

Sector	End Use	Tech Group	Measure Group	Data Sources	Data Validation Approach
Residential	Lighting	Interior lighting	CFL lamps	IOU program data, POS data (ACNeilsen), Retail shelf surveys, Supplier interviews	Web price search
Residential	Lighting	Interior lighting	LED lamps		
Residential	Appliances	Laundry	Clothes washers	POS data (NPD)	Cash-for-Appliances invoice data, Web price search
Residential	Appliances	Cold storage	Refrigerators		
Residential	HVAC	DX	Room AC		
Residential	Electronics	Other plug load	Televisions		Web price search
Residential	Electronics	Office	PC power management	Web price search	none

<u>Retail Price Build-up from Wholesale Prices</u>

For measures that are procured and sold to consumers primarily or exclusively via contractors, we used a "retail price build-up" approach where unit price data was collected at the wholesale level and supplemented by explicit estimation of bulk purchase discounts, contractor mark-ups, warranties, and other factors that determine the average retail price faced by final consumers. This approach closely mirrors the equipment and project pricing practices used by contractors, energy service companies, and program implementers who procure and install energy efficiency measures on behalf of customers.

There are several important advantages to using a "retail price build-up" approach. First, because the population of wholesale equipment distributors is relatively small, the sample sizes required to form a representative share of the total market are also small, especially compared to the sample sizes required when sampling the population of final customers. Second, for measures typically procured and installed by third parties, the wholesale markets are highly competitive (e.g. packaged DX) and unit wholesale prices tend not to vary significantly across manufacturers for similar products, thus reducing and sometimes eliminating the need to acquire data on relative sales volumes in order to develop weighted average wholesale prices. Similarly, some wholesale markets have a very limited number of manufacturers (e.g. remote refrigeration), which also serves to reduce the complexity and data required to develop weighted average wholesale prices. Finally, and perhaps most importantly, this approach allows retail price

[22] http://www.energydataweb.com/cpucFiles/pdaDocs/873/Task%205%20memo_final.pdf

estimates to be explicitly controlled for high volume vs. low volume purchasing practices, variation in contractor markup percentages, warranties, and other pricing factors which can influence variations in final retail unit prices as much or more than variations in wholesale unit prices.

Of course, there are also several challenges associated with the approach of building up retail unit price estimates from wholesale prices. The first of these challenges is that this approach requires access to multiple distributor price lists, which are not often readily available and shared with the general public. Second, actual bulk purchase discounts and contractor markup percentages are highly variable and depend on distributor inventories and the specific relationship between a given distributor and contractor. Addressing this challenge requires leveraging a large volume of actual project records to develop robust averages. A third challenge is trying to account for both recent and historical changes in wholesale equipment prices. While there have recently been large fluctuations in many commodity prices (e.g. copper), initial discussions with the subcontractors have indicated that wholesale unit prices for equipment change much more slowly than other project material costs like those for piping, ducting, and wiring. Because these types of material costs cancel in an incremental cost analysis, the largest potential source of price fluctuation is obviated.

Through the RFQ process summarized earlier, the study team identified five firms that regularly specify, procure, and install energy efficiency technologies on behalf of customers and have ready access to multiple distributor price lists for the measures of interest. These firms also have archives of a large number of actual project cost records. Additionally, the study team identified publically-available raw data and a set of primary data collection activities that were used to supplement the wholesale unit price data and/or validate results. Table 2-3 shows the specific measure groups for which the study team used a "retail price build-up" approach and identifies the specific data sources and primary data collection activities conducted for each such measure group.[23]

[23] While we are aware that the IOUs have extensive archives of rebate invoices for many of these measure groups, those invoices only provide unit price data for high-efficiency technologies, not baseline-efficiency technologies. With the exception of add-on measures like HVAC QM, we feel it is important to obtain both baseline and efficient case measure costs from a single source in order to establish the most robust incremental cost models. That said, IOU data may be appropriately used for data validation purposes.

Table 2-3: Data Sources and Primary Data Collection Activities Used to Support Development of Built-up Retail Prices

Sector	End Use	Tech Group	Measure Group	Data Sources	Data Validation Approach
Residential	HVAC	DX	All	DEG (via AEP affiliate)	Actual project records, contractor interviews, IOU invoice data, and/or representative bids
Residential	HVAC	Space heating	All		
Residential	HVAC	Air distribution	All		
Residential	Water Heating	Water heaters	All		
Residential	Building Shell	Insulation	All		
Residential	Building Shell	Windows	All		
C&I	Lighting	Interior Lighting	All but CFL/LED lamps		
C&I	Lighting	Controls	All	QuEST	
C&I	Building Shell	All	All		
C&I	HVAC	All	All but QM	TRC	
C&I	Pool	All	All		
C&I	Water Heating	All	All		
C&I	Process	All	All	ERS	
C&I	Food Service	All	All		
C&I	Refrigeration	All	All	VACOM	

To develop estimates of average contractor markups, the study team sought to leverage each firm's relationships with contractors and builders to solicit a representative sample of itemized project bids (i.e. with equipment separate from labor) for clearly defined prototypical retrofit projects involving the specific measures of interest. By using the wholesale unit price estimates derived from the distributor price lists, the study team was then able to explicitly back out the contractor markups for each type of equipment included in each bid.[24]

To validate the final built-up retail unit price estimates, the study team leveraged a combination of the Cash-for-Appliances invoice data from the CEC (for central air conditioners, air-source heat pumps, furnaces, and heat pump water heaters), each firm's records of completed projects, and/or IOU current project records involving the specific measures of interest. In cases where the available project records were not sufficient or comprehensive enough to support validation for a particular measure, we leveraged the appropriate firm's relationships with contractors and builders to solicit a sample of representative project bids (separate from the exercise described previously) as a means of validating the built-up retail unit price estimates.

24 Under this approach, warranties and other markups besides contractor profit markups would be included in the estimate.

2.4.3 Installation Labor Costs

For deemed measures that are installed directly by the final customer, estimating full measure costs only requires estimating average retail unit prices. Examples of such measures include residential lighting, appliances, and electronics, as well as some residential water heating measures such as pipe insulation and low-flow showerheads. However, for deemed measures that are installed by third parties (e.g. contractors) on behalf of final customers, estimating full measure costs requires estimating average installation labor costs in addition to average retail unit prices.

For this MCS update, the study team used the *RS Means Cost Data* publications as the primary source for average installation labor *rates* ($/hr) associated with different types of retrofit projects. The RS Means publications are a recognized source for developing construction cost estimates and a common benchmark used by contractors, developers, and builders. In the context of this study, the primary advantages of using the labor rates published by RS Means are that the labor rates are internally consistent (thereby reducing systematic bias in labor cost estimates), easily customizable to specific regions and locations via application of RS Means' city cost indices and location cost factors, and consistent with the labor cost estimation procedures used by many contractors and implementers.

However, the RS Means estimates of the installation labor *hours* required for construction and retrofit projects are often too generic to be reasonably representative of energy efficiency projects. For example, while RS Means provides labor hour estimates for the installation of various types of cooling systems, it does not provide labor hour estimates for several types of HVAC control measures (e.g. demand-control ventilation) and indeed all of the lighting and HVAC maintenance measures in the scope of this MCS update.

The study team therefore sought to develop original estimates of average installation labor hours for each deemed measure in the scope of the MCS update that is typically installed by a third party. Table 2-4 provides an overview of the installation labor data sources and validation approaches used by the study team for each in-scope deemed measure group. The rationale for the study team's preference for each of the data sources Table 2-4 is provided in Section 2.2 of the *Task 5 Report*.[25]

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[25] http://www.energydataweb.com/cpucFiles/pdaDocs/873/Task%205%20memo_final.pdf

Table 2-4: Data Sources and Primary Data Collection Activities to Support Development of Installation Labor Hours by Measure Group

<table>
<tr><th>Sector</th><th>End Use</th><th>Tech Group</th><th>Measure Group</th><th>Data Sources</th><th>Data Validation Approach</th></tr>
<tr><td>Residential</td><td>HVAC</td><td>All</td><td>All</td><td>CATI-based contractor survey</td><td rowspan="3">Cash-for-Appliances invoice data; IOU invoice data; RSMeans</td></tr>
<tr><td>Residential</td><td>Water Heating</td><td>All</td><td>All</td><td rowspan="2">In-depth interviews w/contractors and/or representative bids</td></tr>
<tr><td>Residential</td><td>Building Shell</td><td>All</td><td>All</td></tr>
<tr><td>C&I</td><td>Lighting</td><td>All</td><td>All but CFL/LED lamps</td><td>CATI-based contractor survey</td><td rowspan="2">QuEST project records; IOU invoices; RSMeans</td></tr>
<tr><td>C&I</td><td>Building Shell</td><td>All</td><td>All</td><td>In-depth interviews w/contractors and/or representative bids</td></tr>
<tr><td>C&I</td><td>HVAC</td><td>All</td><td>All</td><td>CATI-based contractor survey</td><td rowspan="3">TRC project records; IOU invoices; RSMeans</td></tr>
<tr><td>C&I</td><td>Pool</td><td>All</td><td>All</td><td rowspan="5">In-depth interviews w/contractors and/or representative bids</td></tr>
<tr><td>C&I</td><td>Water Heating</td><td>All</td><td>All</td></tr>
<tr><td>C&I</td><td>Process</td><td>All</td><td>All</td><td rowspan="2">ERS project records; IOU invoices; RSMeans</td></tr>
<tr><td>C&I</td><td>Food Service</td><td>All</td><td>All</td></tr>
<tr><td>C&I</td><td>Refrigeration</td><td>All</td><td>All</td><td>VACOM project records; IOU invoices; RSMeans</td></tr>
</table>

To validate the final installation labor hour estimates, the study team sought to leverage each subcontractor's in-house records of completed, comparable projects; the IOUs' project invoice histories for comparable projects; and any comparable installation labor hours estimates available in the RS Means publications.

Note that comprehensive presentation of the final data sources and ex ante estimates of market-average unit equipment prices and installation labor costs for each in-scope measure is provided in Sections 3 and 4.

2.5 Conduct Data Analysis

Once the measure-specific data collection plans had been fully implemented and the in-scope cost data had been collected and assembled, the next major task was to analyze the data and develop measure-specific estimates of market-average unit equipment prices and installation labor costs. This task involved a host of data cleaning and development activities, many of which were necessarily tailored to particular technologies and/or datasets. In this subsection, we present and describe the key activities involved in the overall data development and analysis process.

2.5.1 Data Cleaning and Backfilling

While the POS datasets acquired by the study team included extensive information on product-specific characteristics and features, the distributor price lists collected typically included only model number, brand, and unit price information. In order to allow for explicit analysis of incremental cost due to efficiency, the price list records needed to be augmented with a host of product characteristics such as capacity, efficiency, and other key product features that influence price. To do this, the study team used a variety of publically available data sources to either backfill or merge such product characteristics onto each price record. In some cases, Itron's subcontractors (or their distributors) included some key product characteristics along with the basic price list information. In these cases, the study team cross-checked this information with other sources to ensure its accuracy and correct any inconsistencies or data-entry errors.

Wherever possible, the study team used CEC and USDOE regulatory compliance databases to merge key product characteristics onto each price record.[26] The primary purpose of these databases is to act as an official repository of certification reports and compliance filings from manufacturers that produce and sell equipment subject to minimum energy performance standards set by either the State of California or the federal government. These databases have several key features that make them extremely valuable resources in the context of this study and measure cost studies in general. First, they are publically available and updated regularly. Second, they cover both highly-efficient technologies as well as standard-efficiency baseline technologies. Third, and perhaps most importantly, the capacity ratings and energy performance metrics are based on common testing procedures and are therefore directly comparable and reduce or eliminate systematic bias related to manufacturer claims. This latter feature is critical for technologies that either have complex or multiple energy performance metrics (e.g. SEER, EER, COP, EF, combustion efficiency, thermal efficiency) or whose capacities can be determined in a number of different ways (e.g. CFM for direct evaporative coolers).[27]

Regulatory compliance databases are not an all-in-one solution for the data development required for measure cost studies of this scale, however. First, to ensure confidentiality and competitiveness, manufacturers are often allowed to partially mask model numbers in these databases, sometimes making it impossible to reliably merge model-specific price records. Second, these databases obviously do not contain any information for unregulated products. In these cases, the study team then attempted to use two other analogous product databases: the

[26] CEC Appliance Database: http://www.appliances.energy.ca.gov/AdvancedSearch.aspx; USDOE Compliance Certification Database: http://www.regulations.doe.gov/certification-data/

[27] This value can be estimated using different levels of external static pressure, which leads to very different CFM ratings for the same product.

USEPA's Energy Star Qualified Product Database[28] and the AHRI's Directory of Certified Product Performance.[29] These two databases are highly analogous to the CEC's and USDOE's regulatory compliance databases in that most of the technical data (e.g. capacity ratings and energy performance metrics) are based on common testing procedures – the key difference being that submission of such product information to these sites is strictly voluntary for manufacturers, rather than mandatory.

If the sources above did not contain the required data for a given product or class of products, the study team located and acquired product-specific cut sheets and extracted the related information from those individual documents. For many unregulated products, product cut sheets proved to be the only source available to backfill the distributor price records with the information necessary for incremental cost analysis. Even for some regulated products, however, the regulatory compliance databases were sometimes either incomplete or did not contain any product characteristics outside of basic capacity and energy performance criteria. In these cases, the study team supplemented the compliance information with data from product cut sheets.

2.5.2 Hedonic Price Modeling

Once the raw price equipment price data had been cleaned and backfilled with the necessary product characteristics data, the study team then developed and tested econometric models of product prices, often referred to as hedonic price models. This method is a statistical approach to isolating and estimating the relative influence of various individual product features on the product's final, observed price. In the case of the MCS update, the key product feature of interest is usually the energy performance of the equipment (e.g. SEER, EER, AFUE, R-value, etc).

To facilitate easier and more direct interpretation of the results, the hedonic models developed for this study are all linear functions with the following general form:

$$Price = a_0 + b_1X_1 + b_2X_2 + b_3X_3 + \cdots + b_nX_n + \varepsilon$$

where $X_1, X_2, X_3, \ldots X_n$ are individual product features such as capacity, energy performance, color, brand, etc. These X variables can be continuous (e.g. annual kWh consumption, diagonal screen size, horsepower), categorical (e.g. the color of the exterior finish, NEMA enclosure type), or binary (presence or absence of particular feature).

The coefficients on the X variables ($b_1, b_2, b_3, \ldots b_n$), the constant a_0, and the error term ε are the values that are estimated as part of the hedonic modeling process. A dedicated discussion of how to interpret the resulting coefficients for each type of variable is provided later in this

[28] http://www.energystar.gov/productfinder/

[29] https://www.ahridirectory.org/ahridirectory/pages/home.aspx

subsection. Below we provide more detail on how the overall hedonic modeling process was designed and implemented by the study team.

SAS Data Transformation, Documentation, and Analysis Processes

For the hedonic price modeling, all data manipulations and analyses were handled in SAS. Initially, the choice to use SAS as the analysis platform was due to the size of the POS datasets, which were among the first price datasets acquired. However, the study team chose to use SAS (as opposed to Excel or other spreadsheet platforms) for all of the hedonic modeling, regardless of the individual sample sizes. This choice was driven primarily by the fact that SAS-driven analyses provide a high level of transparency and reproducibility. Additionally, using SAS allowed the team to develop and implement consistent data handling and code development rules, which help minimize the risk of introducing random or systematic bias during the data transformation and analysis process.

The basic SAS data analysis process developed and implemented by the study team began with the following steps: import raw data, clean standardize all variable names, and convert text fields to formatted numeric values. The products of these steps are then clean, standardized SAS databases. The study team then developed and applied standard sections of SAS code for creating basic summary tables and frequencies to allow the analyst to examine and understand the relative distributions of unit prices and independent variables within each sample. Importantly, having clean, standardized SAS databases also allowed the study team to develop and apply universal code sets to generate a host of data visualizations – including scatter plots and box-and-whisker plots – and identify first order relationships between price and individual independent variables.

Once such first order relationships were identified, the study team then followed a step-wise selection of independent variables for inclusion in each hedonic price model. In this modeling approach, the independent variables that visually demonstrate first order relationships with price are included in the initial model specification. Model coefficients are then estimated using the *proc glm* procedure in SAS, which generates a host summary statistics on model fit (e.g. R^2, adjusted-R^2, F-statistic, etc). At this point, if additional independent variables are available for a given dataset, the analyst then adds those variables to the model specification one-by-one, generating model coefficients and summary statistics at each step, comparing and evaluating the results of each successive model specification.

It should be understood that while this step-wise model specification approach is designed to be systematic, the determination of the "best" model specification can quickly become more art than science – where the "art" perspective is driven by a particular set of research objectives rather than a universal set of econometric or statistical analysis criteria. In the case of the MCS update, the primary research objective behind the hedonic modeling exercise was to estimate the average incremental costs of products due strictly to energy performance differences. A secondary research objective was to develop model specifications that allow a clear, direct mapping of a predicted measure cost to the corresponding ex ante savings impact estimate in DEER and the IOU workpapers, i.e. enabling internally-consistent cost-effectiveness analysis.

The study team's determination of the "best" model specification, therefore, was grounded in deep investigations of the relationships between the energy efficiency variable(s) and the other key technology parameters specified in DEER/IOU workpapers (e.g. capacity) and how those variables interact with other product characteristics with respect to price. In this context, the primary econometric modeling issue that the study team faced when developing and determining the "best" model specifications was identifying and dealing with multicollinearity.

For many of the in-scope deemed measures, multiple product characteristics may be collinear, i.e. tend to move together with respect to price. Typical examples of collinearity faced by the study team include:

- On-mode power consumption and screen size for televisions (i.e. larger televisions have higher on-mode power requirements)
- Color-rendering index and efficacy (lumens/W) for linear fluorescent lamps (high CRI lamps are often also high efficacy lamps)
- Ballast input wattage, number of lamps, and lamp length for linear fluorescent fixtures (ballast input wattage increases as the number of lamps and/or fixture length increases)

Econometric models that include highly collinear variables will produce estimated coefficients that are not precisely estimated. In principle, greater multicollinearity within a model will result in larger estimated standard errors of the coefficients and reduced statistical significance. To be clear, collinearity is a matter of degree, and there is no irrefutable test for multicollinearity. In this sense, the challenge to analysts is to reduce the degree of collinearity as much as possible. There are several ways to look for collinearity. The following situations provide evidence that multicollinearity may exist:

- The F-statistic for the model is statistically significant but few independent variables are significant
- Randomly dividing the sample in two and estimating the model and the estimated coefficients change significantly
- Dropping an insignificant variable leads to large changes in the statistical significance of other estimated coefficients
- Adding a variable leads to a significant swing in the estimated impact of another variable

Where evidence of collinearity presented itself, the study team attempted to either segment the analysis, re-specify the variables in question, or drop the variables in question from the model specification. The decision of whether to segment, re-specify, or drop variables was in turn dependent on sample sizes and whether the variables in question were central to either the energy performance of the product or other critical DEER parameters (e.g. capacity).

In general, then, the "best" model specification was determined using the following approach:[30]

- Initial model specification developed from visual identification of first-order relationships between price and individual independent variables
- Step-wise expansion of model specification, with an eye towards variables that contribute to higher levels of model fit (R^2, adjusted-R^2) and interactions among independent variables that indicate collinearity
- Sample segmentation, re-specification or dropping of variables as appropriate to minimize collinearity
- Selection of "best fit" model (R^2, adjusted-R^2) whose specification also explicitly addresses: 1) the incremental cost due to efficiency and 2) the other key technology parameters in DEER/IOU workpapers

Additional detail on the technology-specific modeling issues encountered by the study team and their respective resolution is presented in Sections 3.1 to 3.5.

Roll-up weights

For many measures and technologies, the number of independent variables (i.e. product features) used to define measures in DEER and/or the IOU workpapers are often a subset of those that the study team defined in its cost models. This phenomenon relates to the fact that usually only one or two product features impact energy performance (e.g. capacity and SEER/EER/AFUE/etc.), whereas multiple product features typically influence unit price. Figure 2-7 below provides an example for refrigerators.

[30] Note that the hedonic model specifications developed for residential lighting technologies were developed independently by DNV-GL. The modeling approach used by the DNV-GL team is described in detail in Appendix B.

Figure 2-6: Variables in Itron Cost Models vs. Variables in DEER/WP Definitions, Refrigerator Example

Itron Model	
ENERGY STAR	Binary
Capacity	Continuous
Type	Categorical
Quarter	**Dummy**
Color	**Categorical**
Dispenser	Binary
kWh/yr	Continuous

DEER Measure	
ENERGY STAR	Binary
Capacity	Discrete
Type	Categorical
Dispenser	Binary
kWh/yr	Discrete

In order to "roll up" the detailed price modeling results to the DEER/IOU workpaper measure definition "level", it was therefore necessary to develop and apply weights to any model variables not included in the DEER/IOU workpaper measure definitions so that the estimated coefficients for those variables can be aggregated. In the refrigerator example, this step essentially serves to create market average results for the "color" and "quarter" variables (as opposed to color- or quarter-specific results), which are then expressed as constants in the price model as shown in Figure 2-8 below.

Figure 2-7: Aggregating Itron Cost Model Results to Match DEER/WP Measure Definitions, Refrigerator Example

$$P_i = \alpha + \beta_1 ES_i + \beta_2 Capacity_i + \beta_3 Type_i + \beta_4 Quarter_i + \beta_5 Color_i + \beta_6 Dispenser_i + \beta_7 kWh_i + \varepsilon_i$$

$$P_i = \alpha + \beta_1 ES_i + \beta_2 Capacity_i + \beta_3 Type_i + \overline{Quarter_i} + \overline{Color_i} + \beta_6 Dispenser_i + \beta_7 kWh_i + \varepsilon_i$$

Ideally, the data used to develop these roll-up weights should be recent "market shares" or "volume shares" based on large, representative samples of recent purchases in the California market. As part of the larger portfolio of 2010-2012 EM&V studies, the study team was able to have direct access to the most recent and comprehensive market share data available in California. These data sources included:[31]

[31] The POS data acquired from the NPD group for refrigerators, televisions, clothes washers, and room air conditioners included volume shares, so no further data acquisition was required to develop roll-up weights for those technologies.

- 2013 Residential Market Share Tracking – POS data
- 2013 California Lighting and Appliance Saturation Survey – on-site survey data
- 2010-2012 Downstream Lighting Impact Evaluation (WO29) – on-site survey data
- 2013 Commercial Saturation Survey/Commercial Market Share Tracking – on-site survey data
- 2006 California Commercial End-Use Survey – on-site survey data

The details of how these data sources were used and the resulting roll-up weights that were developed and applied for this study are presented in Sections 3.1 to 3.5.

Interpreting hedonic modeling results

In this section, we provide readers unfamiliar with econometric or statistical models with guidance on how to interpret the model coefficients. In a nutshell, the correct interpretation of the model coefficients depends on two things: 1) the type of variable for which a given coefficient has been estimated, and 2) the reference case that was defined for that variable (in the case of categorical and binary variables).

For *categorical variables* (e.g. color) and *binary variables* (e.g. ENERGY STAR qualified), the coefficients can generally be interpreted as "the average price difference between otherwise identical products due to the presence of feature X – relative to the reference case." In most cases, particularly for product features defined as binary variables, the reference case is defined as the absence of a given feature. In this sense, one can interpret the model coefficient for the "dispenser" variable of the refrigerator model as, "on average, prices for all refrigerators with through-the-door ice and/or water dispensers are $521 higher than those without."

For categorical variables, the reference case is identified as the variable with a coefficient value of zero. Again using the refrigerator example, the model shows a zero value for the "freezer on bottom" categorical variable (see Table 3-3 on page 3-5). This zero value identifies "freezer on bottom" as the reference case for purposes of interpreting the model results, and the coefficients estimated for the other categorical variables can be interpreted as the average price difference of alternative refrigerator configurations relative to "freezer on bottom" refrigerators, all else being equal. For example, the estimated coefficient for the "French door" categorical variable (308.33) indicates that, on average, prices for all refrigerators with French doors are $308 higher than those with freezers on the bottom.[32]

[32] Note that for modeling and analysis purposes, the choice of which configuration or category to use as the reference case is arbitrary from an analytic point of view – the results for each variable/category will always be the same relative to each other. The Itron team attempted to use the least expensive and/or most standard product

Since the study team specified all its cost models as linear functions, the coefficients for *continuous variables* (e.g. capacity, SEER, EER, AFUE, R-value, etc.) can be interpreted as “the average price difference between otherwise identical products per unit change in the continuous variable.” In the case of refrigerators, there are two continuous variables defined in the MCS cost model – total capacity in ft^3 and kWh/yr rated consumption. The estimated coefficients for those variables (as shown in Table 3-3 on page 3-5) are 23.79 and -0.47, respectively. For capacity, the coefficient can be interpreted as “the average price of refrigerators *increases* by $23.79 for each *increase* in capacity of 1 ft^3.” For rated consumption, the coefficient can be interpreted as “the average price of refrigerators *decreases* by $0.47 for each *increase* in rated annual electricity consumption of 1 kWh.” Alternatively, the consumption coefficient can also be interpreted as “the average price of refrigerators *increases* by $0.47 for each *decrease* in rated consumption of 1 kWh.”

In addition to the coefficients, the hedonic modeling process also produces a variety of summary statistics that describe the statistical significance of each estimated coefficient, i.e. the probability that the estimated relationship is not a random result. For this study, a statistically significant coefficient is defined as one that reflects a minimum confidence level of 95%, as reflected by a t-statistic greater than 2.0. Strictly speaking, the threshold values for t-statistics that determine statistical significance are dependent on the degrees of freedom, i.e. the sample size. Larger samples have lower t-statistic thresholds for statistical significance, whereas smaller samples have larger t-statistic thresholds for statistical significance. Given the samples sizes that the study team was able to assemble for most measures (100+ points), t-stat values of 2.0 or greater are all statistically significant at the 95% confidence level.[33]

2.5.3 Built-up and Simple Average Estimates

For a significant subset (roughly one quarter) of in-scope measures, it proved difficult, inappropriate, or unnecessary to estimate incremental cost using hedonic modeling. In these cases, the study team used built-up costs developed by specialized subcontractors or simple averaging (either on a matched pair basis or whole-sample basis).

The measure characteristics or market conditions that lead to the decision to use built-up or simple average estimates can be generalized as follows:

configurations when defining the reference cases for modeling purposes but can easily revise the reference case definitions if so desired.

33 Note that the level of statistical significance climbs significantly for coefficients whose t-statistics are larger than 2.0. Given the sample sizes that the study team was able to assemble, t-statistics greater than 2.0 generally have p-values <0.05, t-stats values 3.0 or greater generally have p-values <0.01, and t-stat values greater than 4.0 all have p-values <0.001.

- Measures that in reality are more akin to "projects" rather than one-for-one replacements or add-ons and involve multiple components and highly specialized, turnkey labor, e.g. commercial refrigeration measures
- Measures that are primarily maintenance practices and can include a wide variety of possible interventions, e.g. HVAC maintenance measures
- Small markets with a limited number of products but wide variation in distributor pricing practices for identical products, e.g. food service equipment
- Markets where final pricing is typically negotiated with specific customers, e.g. network power management software

The details of the specific market conditions, data availability, data sources, and methods used to develop the built-up or simple average estimates produced by the study team are presented in Section 3.6 to 3.8.

2.5.4 Validation and Benchmarking

As noted previously, independent validation of the predicted average prices produced by the study team (whether through hedonic modeling, built-up estimates, or simple averages) was a critical step in the study team's overall analysis approach.

For certain technologies, the study team was able to access large sets of "out of sample" price data to use for this model validation step, namely IOU program data and the complete set of customer invoices from the CEC's C4A program. For most technologies, however, the amount of "out of sample" price data readily available for this validation step was more limited. In these cases, the study team developed necessarily smaller validation data sets based on web-based price lookups from online retailers or distributors and/or contractor price quotes from artificial project bids developed by the study team.[34]

These small-sample validation data sets typically contain 20-40 total data points, representing price quotes for six to eight specific products drawn from three to four different "out of sample" price sources. Where possible, the study team leveraged "top seller" and "most popular" product lists available on retailer or distributor websites to identify the product specifications (and associated matched pairs) with the largest market share and therefore the highest priority/value against which to validate predicted prices.

[34] Note that for the model validation exercise, the Itron team collected "out of sample" price data for products with as many of the product characteristics defined in the Itron cost models as possible. In many cases, this level of product specification includes technology characteristics that are not included in the corresponding DEER/workpaper measure definitions. The Itron team decided to validate the cost models at this more detailed level primarily to increase the level of direct comparability between predicted prices and out-of-sample observed prices, therefore increasing the overall value of the validation exercise.

For large capital equipment (e.g. chillers, boilers, packaged DX, etc), there were typically no "out of sample" price data readily available from web-based price lookups. In these cases, the study team used a combination of artificial project bids, previous DEER estimates, IOU workpaper estimates, and average unit prices from RSMeans for the validation exercise.

Similarly for installation labor hours, the "out of sample" data readily available to the study team typically consisted of some combination of artificial project bids, previous DEER estimates, IOU workpaper estimates, and average labor hours from RSMeans.

2.5.5 Uncertainty

As a byproduct of using hedonic price modeling to estimate incremental costs for the majority of the in-scope deemed measures, the study team was also able to develop uncertainty estimates for the predicted average price (full or incremental) of energy-efficient products. Similarly, where installation labor hours were estimated based on large sample CATI surveys of lighting and HVAC contractors, the study team was able to develop uncertainty estimates for the estimated average installation costs. To be clear, the study team was not able to explicitly quantify uncertainty bounds for built-up or simple average estimates of unit equipment prices and installation labor costs. However, validation benchmarks are provided for all in-scope measures (both unit equipment prices and installation labor costs).

For measures where incremental cost is the difference between the modeled prices of each matched pair of baseline and high-efficiency products (with all other features held constant), the uncertainty of the incremental cost estimate is represented by the standard error associated with the coefficient of the energy-related variable (e.g. kWh/yr, EER, SEER, R-value, AFUE, MEF, etc) defined for that technology.

For add-on measures, the uncertainty of the incremental cost estimate is represented by the mean absolute error divided by the sample mean. This quantity provides a rough estimate of the standard error of the predicted incremental cost for add-on measures, where incremental cost is equal to full cost.[35] Mean absolute error is common measure of the average magnitude of the forecast error for hedonic models (over all predicted values). The ratio of mean absolute error to the sample mean provides a rough estimate of the average error associated with a particular predicted point value and can be compared to the absolute value of the associated incremental cost estimate. For example, the predicted price for a 30hp, NEMA 1 enclosure, no bypass VFDs is $1,308.64, with a mean absolute error/sample mean value of $187.67. The study team's rough estimate of the standard error of that predicted price can thus be interpreted as 187/1308 or 14.3 percent.

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[35] A more strict assessment of the standard error associated with full costs predicted by hedonic models requires Monte Carlo analysis but is more time-consuming.

3

Unit Equipment Prices – Final Data Sources and Results

Having provided an overview of the research approach developed and implemented by the study team, this section presents the final data sources and ex ante estimates of market-average unit equipment prices for each in-scope measure. This section also provides additional detail and narratives on the technology-specific modeling issues encountered, the respective resolutions, and the data sources and methods used to develop roll-up weights (wherever necessary). The complete set of recommended full and incremental equipment values (including installation costs for early replacement and replace-on-burnout measures) is provided Appendix F.

Results are shown for each in-scope technology or measure, but the presentation and discussion of results are grouped by technologies and measures with common data sources and/or data analysis methods. In each of the subsections that follow, the results are presented using the following structure:

- Highlights from the data development effort (challenges, issues, and resolutions)
- Summary of all final data sources used
- Market assessment findings resulting from the data development effort
- Highlights from the modeling/analysis process (challenges, issues, and resolutions)
- Highlights from the development of roll-up weights (if any)
- Key model results and findings

It is important to note that the summaries and discussions below were designed to be supplementary to the discussions of the general data collection, data development, and data analysis methods and approaches presented previously in Section 2.

3.1 Appliances and Electronics

3.1.1 Data Development Process

For in-scope appliances and electronics measures (refrigerators, clothes washers, and televisions), the study team acquired comprehensive POS data from the NPD Group. This dataset came populated with dozens of product characteristics for each record, along with the average, actual selling price in each of 11 previous quarters (Q1 2010 through Q2 2012).[1] Due the comprehensiveness of the NPD POS data, the data development efforts were minimal and focused primarily on working with NPD to limit the number of records whose detailed information was "masked" in order to conform to NPD's confidentiality agreements with its respective retail partners.[2]

Table 3-1 shows the final data sources used for the unit price estimates for appliances and electronics. As the table shows, the product characteristics and volume share (share of total units sold) data included in the NPD POS data obviated any need to acquire other data sources to backfill the price records or develop roll-up weights. To validate the predicted unit prices for appliances and electronics, the study team used invoices from the CEC's Cash for Appliances (C4A) program, which covered roughly the same period (2010-2011). The C4A dataset included 56,608 invoices for refrigerators and 36,350 invoices for clothes washers. For televisions, the study team used price lookups from six online retailers to validate predicted prices.[3]

Table 3-1: Final Data Sources for Unit Price Estimates – Appliances and Electronics

<table>
<tr><th>Technology</th><th>Primary Price Data Source</th><th>Product Characteristics Source</th><th>Roll-up Weight Source</th><th>Price Validation Source</th></tr>
<tr><td>Refrigerators</td><td colspan="3" rowspan="3">NPD POS data</td><td rowspan="2">C4A</td></tr>
<tr><td>Clothes Washers</td></tr>
<tr><td>Televisions</td><td>Online retailer price lookups</td></tr>
</table>

3.1.2 Market Assessment Findings

While the refrigerator and clothes washer markets continue to evolve on a gradual course along with the respective Energy Star product specifications, the television market has undergone dramatic changes in recent years with the phase-in of digital-only signal transmission, the associated retirement of cathode ray tube televisions, and advances in flat-screen display technology. To put the current television market and trends into perspective, Table 3-2 shows the market shares of televisions recently sold in California by type. As the table shows, liquid crystal display (LCD) televisions now account for nearly 90 percent of new television sales, with plasma televisions accounting for a rather steady 10 percent share. However, within LCD televisions, the market share of light emitting diode (LED) backlit units has grown strongly and

1 See Appendix A of the *Task 5 Report* for a complete list of the product attributes included in the NPD POS data.

2 The original NPD POS data included model numbers, whose inclusion resulted in "masking" the attributes for roughly half of the sample. Since the POS data was already populated with all the product characteristics required for incremental cost analysis, the study team determined that having model numbers in the dataset was superfluous. Removing the model number reporting allowed product attributes to be "unmasked" for roughly 5,000 records (representing ~1.5 million in unit sales), increasing the size of the analysis sample by 40%.

3 Best Buy, Sears, Amazon, Fry's, Newegg.com, and Target.

steadily over the past two years, while the market share of cold-cathode fluorescent lamp (CCFL) backlit units appears to be in steady decline.

Table 3-2: Relative Sales Volume of Televisions Sold in California by Type, 2010-2012 (source: NPD)

	LCD					
Quarter/Year	**CCFL**	**LED**	**OLED**	**Plasma**	**Portable**	**Rear Projection**
Q1 2010	79.3%	6.8%	0.0%	10.6%	2.9%	0.4%
Q2 2010	68.7%	12.1%	0.0%	12.3%	6.5%	0.4%
Q3 2010	66.5%	17.0%	0.0%	14.3%	1.8%	0.3%
Q4 2010	67.4%	18.8%	0.0%	11.3%	2.1%	0.4%
Q1 2011	62.6%	23.1%	0.0%	12.9%	1.0%	0.4%
Q2 2011	58.6%	28.1%	0.0%	11.7%	1.1%	0.4%
Q3 2011	54.5%	32.4%	0.0%	12.1%	0.6%	0.3%
Q4 2011	59.6%	30.1%	0.0%	9.8%	0.3%	0.2%
Q1 2012	56.3%	32.4%	0.0%	10.6%	0.4%	0.3%
Q2 2012	50.3%	39.3%	0.0%	9.8%	0.3%	0.2%

These trends are highly relevant to IOU program planning, as it appears that the market is moving quickly to LED-backlit LCD units, which also happen to be the most energy-efficient units available. For this MCS update, the study team focused its incremental cost modeling and analysis on CCFL- and LED-backlit LCD units and plasma units and did not invest any project resources analyzing portable, rear projection, or organic LED (OLED) backlit LCD televisions.

3.1.3 Modeling Process

The overriding analytic issue for appliances and electronics was accounting for price changes over time (e.g. separating the influence of inflation from real price declines for televisions) and seasonal pricing. To transform the time series data from nominal to real prices, the study team applied the Consumer Price Index (CPI).[4] The team then estimated time fixed effects (e.g. seasonal pricing and real price trends) through specification of dummy variables for each quarter.

For refrigerators, the initial model specification included a capacity variable (ft^3 volume), but the sample included both full-size and compact refrigerators, which in turn lead to poor model fits and some counter-intuitive coefficients. Limiting the analysis sample to only full-size units greatly improved model fit and aligned the sample and model specification with the DEER and

[4] Department Store Inventory Price Index for Major Appliances (series ID LIUR0000SL00019). Note that CPI is a monthly index, while the NPD POS data were quarterly. The study team used the CPI values from the first month of each quarter to transform the quarterly average prices to real prices, i.e. Jan 2011 = Q1 2011.

IOU workpaper measure definitions. Similarly for clothes washers, the initial model specification included a categorical variable for type (top-loading vs. front-loading), which resulted in poor model fit. Segmenting the analysis by clothes washer type resulted in improved model fits and statistically significant coefficients for all the variables of interest.

For televisions, the initial model specifications developed by the study team used screen size as a continuous variable and type as a categorical variable. These models displayed good levels of model fit and intuitive coefficients with the key exception being a small, non-statistically significant *negative* incremental cost for on-mode power (in watts) – the key energy performance criterion in the current Energy Star product specification. In order to determine if this was a real effect, or if it was the result of collinearity between on-mode power consumption and screen size, the study team created separate models for discrete screen sizes of LED- and CCFL-backlit LCD televisions to completely remove the effect of screen size on price and isolate the effect of on-mode power more explicitly. The screen sizes with the largest share of unit sales in the dataset were 19 inches, 22 inches, 32 inches, 40 inches, 46 inches, and 55 inches – which align well with those used in the IOU workpapers. This approach allowed the study team to compare results across the size-specific models in order to identify any patterns in incremental cost (e.g. divergent or convergent) across televisions of different screen sizes.

To develop separate models for each of these specific screen sizes, the study team took the set of initial model specifications that were applied to all screen sizes together (by type) and re-estimated those models using the screen size-specific datasets.[5] The individual screen size-specific models were then customized to account for price-influencing attributes that are unique or prevalent within specific screen sizes (e.g. 480 Hz refresh rates for large screens, 720p resolution for smaller screens). The net result of this exercise was to corroborate the initial finding that there is a small, and generally non-statistically significant, *negative* incremental cost for on-mode power in CCFL- and LED-backlit LCD televisions. The tables below present the model results for the 46” CCFL- and LED-backlit LCD televisions, as well as the all screen-size model for plasma televisions,[6] although readers should note that the full set of results from all of the screen size-specific models are available upon request.

[5] In addition to on-mode power and sleep-mode power, variables in these model specifications included 2D/3D; Picture-In-Picture; DVD included; networking capable, with or without a built-in browser; quarter; and brand.

[6] In light of the findings from the size-specific modeling of LCD televisions, the narrower range of screen sizes for plasma televisions, the small market share of plasmas, and the good model fit achieved when modeling all plasma screen sizes together, the study team concluded it was of marginal value to develop size-specific models for plasmas.

Table 3-3: Hedonic Price Model Results for Residential Refrigerators

Technology	Model Variables			Model Results					Model Stats
	Name	**Type**	**Values**	**Coefficient**	**t-stat**	**Standard Error**	**Roll-up Wts**	**Wtd Coefficient**	
Refrigerators (full size residential)	ENERGY STAR	Binary	Yes	-11.64	-1.03	11.340	N/A	-11.64	N observations
			No	0.00	--	--	N/A	0.00	7,372
	Capacity (Volume ft3)	Continuous	7.8 - 31	23.79	17.60	1.350	N/A	23.79	N unit sales
	Type	Categorical	Freezer on Bottom	0.00	--	--	N/A	0.00	470,719
			Freezer on Top	-391.09	-24.90	15.740	N/A	-391.09	R2
			French Doors	308.33	18.40	16.780	N/A	308.33	0.860
			Side-by-Side	-548.29	-29.20	18.750	N/A	-548.29	Intercept
	Quarter	Categorical	1	0.00	--	--	0.129	-43.58	726.700
			2	-34.90	-3.90	8.860	0.271		MAE
			3	-42.00	-4.90	8.530	0.361		
			4	-79.30	-8.70	9.080	0.239		Contr. Markup
	Color	Categorical	White	0.00	--	--	0.395	86.62	N/A
			Bisque	71.51	2.51	28.510	0.009		
			Black	14.77	1.92	7.710	0.185		
			Other	169.17	6.17	27.420	0.010		
			Stainless	250.38	32.31	7.750	0.312		
			Stainless Look	40.00	3.96	10.100	0.090		
	Dispenser	Binary	Yes	521.50	42.90	12.150	N/A	521.50	
			No	0.00	--	--	N/A	0.00	
	kWh/yr	Continuous	253 - 728	-0.47	-5.20	0.090	N/A	-0.47	

Table 3-4: Hedonic Price Model Results for Residential Clothes Washers

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
Clothes Washers (side by side, top loading)	Modified Energy Factor	Continuous	1.26-3.61	38.91	4.89	7.959	N/A	38.91	N observations
	Compartment Capacity	Continuous	2.5-4.7	202.93	14.74	13.764	N/A	202.93	512
	Soil Sensor	Categorical	Yes	58.60	6.55	8.948	0.131	8.48	N unit sales
			No	0.00	.	.	0.860		112,589
			Not Specified	87.15	3.54		0.009		R2
	Quarter	Categorical	1	-17.07	-2.37	7.206	0.186	7.29	0.903
			2	10.56	1.60	6.602	0.259		Intercept
			3	23.71	3.83	6.183	0.326		-400.447
			4	0.00	.	.	0.229		MAE
	Electronic Controls	Binary	Yes	44.53	6.20	7.177	0.421	18.75	111.074
			No	0.00	.	.	0.579		Contr. Markup
	Brand	Categorical	Amana	-12.44	-0.31	40.224	0.004	-5.04	N/A
			Estate	-12.60	-0.01	1105.372	0.000		
			Fisher & Paykel	-125.22	-4.17	30.034	0.006		
			GE	-55.49	-8.53	6.508	0.217		
			Hotpoint	-52.84	-3.39	15.591	0.026		
			LG Electronics	69.57	5.06	13.752	0.085		
			Maytag	9.14	1.35	6.747	0.195		
			Samsung	26.18	1.59	16.414	0.056		
			Whirlpool	0.00	.	.	0.412		
	Color	Categorical	Bisque	122.93	0.36	342.555	0.001	78.06	
			Black	213.15	0.59	363.808	0.000		
			Red	223.16	0.64	350.452	0.000		
			Stainless	146.66	0.42	351.675	0.000		
			Stainless Look	211.94	0.64	333.594	0.036		
			White	72.88	0.22	333.355	0.962		
			Other	0.00	.	.	0.000		

Table 3-4: Hedonic Price Model Results for Residential Clothes Washers (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	**Type**	**Values**	**Coefficient**	**t-stat**	**Standard Error**	**Roll-up Wts**	**Wtd Coefficient**	
Clothes Washers (stackable, front loading)	Modified Energy Factor	Continuous	1.8-3.88	28.90	2.24	12.878	N/A	28.90	N observations
	Compartment Capacity	Continuous	2-4.4	233.55	14.97	15.601	N/A	233.55	754
	Steam Feature	Binary	Yes	58.76	4.30	13.666	0.292	17.13	N unit sales
			No	0.00	.	.	0.708		89,778
	Sensor Type	Categorical	Both Load and Soil	93.13	4.45	20.943	0.061	10.62	R2
			Soil Only	80.85	6.32	12.792	0.225		0.740
			Load Only	-44.85	-3.06	14.654	0.319		Intercept
			Not Specified	134.56	2.83	47.512	0.008		-342.066
			No Sensor	0.00	.	.	0.386		MAE
	Quarter	Categorical	1	1.24	0.11	11.682	0.228	16.22	142.312
			2	26.36	2.41	10.932	0.287		Contr. Markup
			3	28.45	2.63	10.822	0.295		N/A
			4	0.00	.	.	0.191		
	Brand	Categorical	Amana	-112.23	-0.39	287.098	0.000	22.60	
			Bosch	185.65	5.03	36.890	0.014		
			Electro Brand	178.95	0.38	470.925	0.000		
			Electrolux	29.04	1.00	29.161	0.026		
			Frigidaire	-122.14	-6.54	18.678	0.073		
			GE	58.44	1.96	29.796	0.022		
			LG Electronics	88.55	6.23	14.209	0.200		
			Maytag	44.51	2.39	18.647	0.067		
			Samsung	17.72	1.47	12.085	0.354		
			Whirlpool	0.00	.	.	0.243		
	RPMs	Categorical	720-1100	-8.31	-0.15	54.827	0.287	28.92	
			>1100	44.25	0.82	53.943	0.707		
			Unspecified	0.00	.	.	0.006		
	Color	Categorical	Bisque	2.65	0.00	1274.646	0.000	98.60	
			Black	104.33	1.25	83.785	0.022		
			Blue	41.12	0.46	89.206	0.012		
			Green	-62.50	-0.19	330.656	0.000		
			Red	93.28	1.16	80.555	0.047		
			Stainless	63.70	0.04	1513.555	0.000		
			Stainless Look	223.32	2.82	79.250	0.097		
			White	85.15	1.08	78.778	0.820		
			Other	0.00	.	.	0.003		
	Number of Wash Cycles	Categorical	3 to 11 cycles	-61.09	-1.56	39.119	0.737	-50.75	
			12 to 19 cycles	-27.06	-0.68	39.610	0.239		
			20 or more cycles	59.07	1.07	55.456	0.013		
			Not Specified	0.00	.	.	0.010		

Table 3-5: Hedonic Price Model Results for Televisions

Technology	Model Variables			Model Results					Model Stats
	Name	**Type**	**Values**	**Coefficient**	**t-stat**	**Standard Error**	**Roll-up Wts**	**Wtd Coefficient**	
LED-backlit LCD Televisions (46" screen size)	On-mode Power (W)	Continuous	42-136	1.76	1.13	1.557	N/A	1.760	N observations
	Sleep-mode Power (W)	Continuous	0.1-1	-223.73	-1.51	148.324	N/A	-223.727	170
	Brand	Categorical	All Other	5.16	0.12	41.787	0.064	140.552	N unit sales
			Coby	-22.02	-0.04	606.713	0.000		40,028
			Element	17.23	0.15	112.785	0.006		R2
			Hitachi	204.97	0.29	717.892	0.000		0.880
			JVC	541.41	1.10	492.857	0.000		Intercept
			Philips	-97.15	-0.56	172.797	0.013		674.970
			Samsung	213.89	1.48	144.675	0.541		MAE
			Sansui	-24.26	-0.05	536.539	0.000		163.194
			Sharp	196.88	1.28	154.094	0.020		Contr. Markup
			Sony	86.04	0.59	145.458	0.146		N/A
			TCL	-1.73	-0.01	248.413	0.001		
			Toshiba	151.37	2.43	62.256	0.081		
			Vizio	-227.45	-1.43	158.860	0.014		
			Westinghouse	0.00	.	.	0.115		
	Refresh Rate (Hz)	Categorical	60	-268.32	-4.03	66.604	0.058	-241.080	
			120	-274.49	-6.84	40.135	0.821		
			240	0.00	.	.	0.120		
	2D vs 3D	Categorical	2D	-193.84	-4.67	41.504	0.527	-102.118	
			3D	0.00	.	.	0.473		
	Network Connectivity	Categorical	No network connectivity	0.00	.	.	0.264	38.442	
			Connected, no browser	55.26	0.19	294.966	0.318		
			Connected w/built-in browser	49.97	0.17	301.306	0.418		
			Connected (unspecified)	-171.52	-0.26	664.316	0.000		
	Picture in a Picture	Binary	Yes	37.88	0.97	39.101	0.331	12.537	
			No	0.00	.	.	0.669		
	Analog Tuner	Binary	Yes	209.83	1.42	147.421	0.997	209.175	
			No	0.00	.	.	0.003		
	Apps Included	Binary	Yes	46.80	0.18	258.579	0.735	34.409	
			No	0.00	.	.	0.265		
	Quarter	Categorical	1	123.64	4.29	28.849	0.661	96.550	
			2	73.90	2.51	29.391	0.201		
			3	0.00	.	.	0.138		

Table 3-5: Hedonic Price Model Results for Televisions (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	**Type**	**Values**	**Coefficient**	**t-stat**	**Standard Error**	**Roll-up Wts**	**Wtd Coefficient**	
CCFL-backlit LCD Televisions (46" screen size)	On-mode Power (W)	Continuous	72.8-238.7	-0.25	-0.34	0.741	N/A	-0.253	N observations
	Sleep-mode Power (W)	Continuous	0-0.9	-142.83	-0.90	158.614	N/A	-142.832	128
	Brand	Categorical	All Other	72.63	1.24	58.668	0.020	97.387	N unit sales
			Apex	-132.45	-2.27	58.237	0.111		39,431
			Hitachi	43.99	0.08	518.486	0.000		R2
			JVC	218.43	0.82	267.674	0.000		0.968
			LG	191.21	1.15	166.235	0.001		Intercept
			Magnavox	19.88	0.27	73.583	0.034		994.113
			Mitsubishi	-73.09	-0.18	414.155	0.000		MAE
			Philips	-20.29	-0.28	71.409	0.079		121.538
			SEIKI	21.31	0.20	109.095	0.001		Contr. Markup
			Samsung	117.60	1.44	81.862	0.435		N/A
			Sansui	67.56	0.18	370.745	0.000		
			Sanyo	65.15	1.18	54.984	0.143		
			Sharp	109.06	0.70	156.268	0.000		
			Sony	292.98	4.59	63.798	0.174		
			Toshiba	259.42	0.49	525.864	0.000		
			Westinghouse	0.00	.	.	0.002		
	Refresh Rate (Hz)	Categorical	60	-76.83	-1.28	59.863	0.666	-62.130	
			120	-33.12	-0.55	60.532	0.331		
			240	0.00	.	.	0.003		
	2D vs 3D	Categorical	2D	-368.61	-2.07	178.460	1.000	-368.458	
			3D	0.00	.	.	0.000		
	Network Connectivity	Categorical	No network connectivity	0.00	.	.	0.541	73.043	
			Wireless built-in	352.23	3.28	107.505	0.026		
			Ethernet	195.05	1.19	164.097	0.001		
			Network ready, no dongle	147.35	2.51	58.759	0.432		
	Picture in a Picture	Binary	Yes	-109.16	-5.50	19.838	0.334	-36.511	
			No	0.00	.	.	0.666		
	Analog Tuner	Binary	Yes	18.89	0.22	85.676	0.998	18.860	
			No	0.00	.	.	0.002		
	Apps Included	Binary	Yes	-96.44	-0.47	206.395	0.028	-2.736	
			No	0.00	.	.	0.972		
	Advanced Proprietary OS	Binary	Yes	-178.31	-0.81	219.218	0.029	-5.135	
			No	0.00	.	.	0.971		
	Quarter	Categorical	1	-7.21	-1.05	6.858	0.373	-22.863	
			2	-70.78	-7.94	8.917	0.138		
			3	-100.20	-9.41	10.644	0.104		
			4	0.00	.	.	0.385		

Table 3-5: Hedonic Price Model Results for Televisions (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	**Type**	**Values**	**Coefficient**	**t-stat**	**Standard Error**	**Roll-up Wts**	**Wtd Coefficient**	
Plasma Televisions (all screen sizes)	Display size (in. diagonal)	Continuous	42-65	25.27	9.15	2.762	N/A	25.268	N observations
	On-mode Power (W)	Continuous	69-388	5.80	10.24	0.566	N/A	5.803	921
	Sleep-mode Power (W)	Continuous	0.1-0.9	-40.08	-0.77	51.945	N/A	-40.078	N unit sales
	Brand	Categorical	All Other	199.34	3.33	59.804	0.140	253.451	523,779
			LG	79.23	1.35	58.847	0.072		R2
			Panasonic	366.94	6.58	55.800	0.386		0.792
			Pioneer	578.43	0.39	1493.425	0.000		Intercept
			Samsung	206.45	3.63	56.819	0.379		-1459.922
			Zenith	0.00	.	.	0.023		MAE
	Resolution	Categorical	1024 x 768	-66.73	-2.52	26.506	0.433	-53.953	350.618
			1280 x 1080	-650.58	-0.17	3783.017	0.000		Contr. Markup
			1280 x 720	-541.77	-8.75	61.894	0.018		N/A
			1365 x 768	-367.40	-7.00	52.454	0.027		
			1366 x 768	-30.16	-0.86	35.223	0.170		
			1920 x 1080	0	.	.	0.352		
	2D vs 3D	Categorical	2D	0	.	.	0.791	93.322	
			3D	446.57	16.88	26.456	0.209		
	Quarter	Categorical	1	-2.98	-0.16	19.187	0.268	25.648	
			2	99.15	4.21	23.576	0.167		
			3	62.06	2.56	24.223	0.159		
			4	0	.	.	0.406		

3.1.4 Roll-up Weights

The study team developed roll-up weights for several variables that had statistically significant price effects but no relationship to energy performance and are not present in DEER/IOU workpaper measure definitions. For refrigerators, these variables included calendar quarter, color, and through-the-door water and ice dispensers. For clothes washers, these variables included quarter, color, and brand (for both top-loading and front-loading types); soil sensor and electronic controls (for top-loading only); and steam, sensor type, RPMs, and number of cycles (for front-loading only). For televisions, these variables included quarter, brand, refresh rate, 3D, network connectivity, resolution, and built-in DVD.

As noted earlier, the NPD POS data included volume shares for each record, and the study team used this data directly to develop market shares and roll-up weights for all of the variables above.

3.1.5 Model Results and Findings

Table 3-6 presents the study team's estimates of incremental equipment prices for residential refrigerators, clothes washers, and televisions.[7]

As the table shows, the study team found statistically significant but relatively low incremental costs for full-size, Energy Star-compliant refrigerators. These estimates range from $18 to $40 per unit, depending on total volume, door configuration, and availability of through-the-door ice. These incremental cost estimates are 60-80 percent lower than the current DEER estimates. Similarly, the study team also found statistically significant but relatively low incremental costs for top-loading, Energy Star-compliant clothes washers, ranging from $28 to $44 per unit, depending on capacity and efficiency level. These incremental cost estimates are 60-75 percent lower than the current DEER estimates. For front-loading clothes washers, the study team found much higher, statistically significant incremental costs ($108 to $221 per unit). However, it should be noted that the latter estimates mainly reflect the DEER baseline assumption (front-loading replacing top-loading), rather than a dramatic difference in the magnitude of the coefficient on the MEF variable between the front-loading and top-loading price models. In fact, the MEF coefficient in the front-loading model is slightly smaller than that in the top-loading model (28.9 vs. 38.9).

For televisions, the study team found very little consistent evidence of statistically significant incremental costs due to on-mode and sleep-mode power when examining model results across the screen size-specific models. In fact, the only consistent finding for televisions is a non-statistically significant, *negative* incremental cost, i.e. higher average prices for higher on-mode and sleep-mode power consumption.

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[7] The complete set of incremental cost estimates based on the measure definitions from READI v.1.0.4 "Draft Combined DEER 2011 and DEER 2014 plus IOU Ex Ante for the 2013-14 Cycle" is provided in Appendix F.

Table 3-6: Incremental Equipment Price Estimates for Residential Refrigerators, Clothes Washers, and Televisions

Technology	Measure Source	Match Pair	Description	Modeled Price	IMC
Refrigerators (full size residential)	DEER Measures	Baseline	Bottom Mount Freezer, Large, 573 rated kWh/yr	$993.00	-
		Measure	Energy Star Bottom Mount Freezer without through-the-door ice - large (16.5-25 ft3 TV) - 487 kWh/yr	$1,022.00	$28.87
		Baseline	Refrigerator: Bottom Mount Freezer, Small; 518 rated kWh/yr	$817.00	-
		Measure	Energy Star(R) Refrigerator: Bottom Mount Freezer without through-the-door ice - small (8-16.5 ft3 TV) - 447 kWh/yr	$839.00	$21.80
		Baseline	Refrigerator: Side Mount Freezer, Large; 665 rated kWh/yr	$551.00	-
		Measure	Energy Star(R) Refrigerator: Side Mount Freezer without through-the-door ice - large (23-31ft3 TV) - 565 kWh/yr	$586.00	$35.46
		Baseline	Side Mount Freezer, Large, Ice Maker; 730 rated kWh/yr	$1,041.00	-
		Measure	Energy Star Side Mount Freezer with through-the-door ice - large(23-31 ft3 TV) - 620 kWh/yr	$1,082.00	$40.17
		Baseline	Refrigerator: 620 rated kWh/yr	$381.00	-
		Measure	Energy Star(R) Refrigerator: Side Mount Freezer without through-the-door ice - medium (15-23 ft3 TV) - 528 kWh/yr	$413.00	$31.69
		Baseline	Refrigerator: 639 rated kWh/yr	$894.00	-
		Measure	Energy Star(R) Refrigerator: Side Mount Freezer with through-the-door ice - medium (15-23 ft3 TV) - 543 kWh/yr	$928.00	$33.58
		Baseline	Refrigerator: Top Mount Freezer, Large; 532 rated kWh/yr	$663.00	-
		Measure	Energy Star(R) Refrigerator: Top Mount Freezer without through-the-door ice - large (20-25 ft3 TV) - 452 kWh/yr	$689.00	$26.04
		Baseline	Refrigerator: Top Mount Freezer, Medium; 469 rated kWh/yr	$574.00	-
		Measure	Energy Star(R) Refrigerator: Top Mount Freezer without through-the-door ice - medium (15-20 ft3 TV) - 399 kWh/yr	$595.00	$21.33
		Baseline	Top Mount Freezer, Small; 420 rated kWh/yr	$478.00	-
		Measure	Energy Star Top Mount Freezer without through-the-door ice - small (10-15 ft3 TV) - 357 kWh/yr	$496.00	$18.03

Table 3-6: Incremental Equipment Price Estimates for Residential Refrigerators, Clothes Washers, and Televisions (continued)

Technology	Measure Source	Match Pair	Description	Modeled Price	IMC
Clothes Washers (side by side, top loading)	Workpaper Measures	Baseline	Top-loading, Title 20 code minimum, MEF=1.26, assumed 3.5 ft3 capacity	$466.37	-
		Measure	Top-loading, CEE Tier 1, MEF = 2.0, assumed 3.5 ft3 capacity	$495.17	$28.79
		Measure	Top-loading, CEE Tier 2, MEF = 2.2, assumed 3.5 ft3 capacity	$502.95	$36.57
		Measure	Top-loading, CEE Tier 3, MEF = 2.4, assumed 3.5 ft3 capacity	$510.73	$44.36
		Baseline	Top-loading, Title 20 code minimum, MEF=1.26, assumed 4.0 ft3 capacity	$567.84	-
		Measure	Top-loading, CEE Tier 1, MEF = 2.0, assumed 4.0 ft3 capacity	$596.63	$28.79
		Measure	Top-loading, CEE Tier 2, MEF = 2.2, assumed 4.0 ft3 capacity	$604.41	$36.57
		Measure	Top-loading, CEE Tier 3, MEF = 2.4, assumed 4.0 ft3 capacity	$612.20	$44.36
Clothes Washers (stackable, front loading)	Workpaper Measures	Baseline	Top-loading, Title 20 code minimum, MEF=1.26, assumed 3.5 ft3 capacity	$466.37	-
		Measure	Front-loading, CEE Tier 1, MEF = 2.0, assumed 3.5 ft3 capacity	$676.50	$210.12
		Measure	Front-loading, CEE Tier 2, MEF = 2.2, assumed 3.5 ft3 capacity	$682.28	$215.90
		Measure	Front-loading, CEE Tier 3, MEF = 2.4, assumed 3.5 ft3 capacity	$688.05	$221.68
		Baseline	Top-loading, Title 20 code minimum, MEF=1.26, assumed 4.0 ft3 capacity	$567.84	-
		Measure	Front-loading, CEE Tier 1, MEF = 2.0, assumed 4.0 ft3 capacity	$676.50	$108.66
		Measure	Front-loading, CEE Tier 2, MEF = 2.2, assumed 4.0 ft3 capacity	$682.28	$114.44
		Measure	Front-loading, CEE Tier 3, MEF = 2.4, assumed 4.0 ft3 capacity	$688.05	$120.22
LED-backlit LCD Televisions (46" screen size)	Workpaper Measures	Baseline	Title 20 code minimum, 129.2 W on-mode power, 1 W sleep mode power, assumed 868 in2 screen area	$867.12	-
		Measure	Energy Star 5.1 + 20%, 72.7 W on-mode power, assumed 1 W sleep mode power, 868 in2 screen area	$767.67	($99.45)
		Measure	Energy Star 5.1 + 35%, 59.1 W on-mode power, assumed 1 W sleep mode power, 868 in2 screen area	$743.73	($123.38)
CCFL-backlit LCD Televisions (46" screen size)	Workpaper Measures	Baseline	Title 20 code minimum, 129.2 W on-mode power, 1 W sleep mode power, assumed 868 in2 screen area	$510.04	-
		Measure	Energy Star 5.1 + 20%, 72.7 W on-mode power, assumed 1 W sleep mode power, 868 in2 screen area	$524.34	$14.30
		Measure	Energy Star 5.1 + 35%, 59.1 W on-mode power, assumed 1 W sleep mode power, 868 in2 screen area	$527.78	$17.74
Plasma Televisions (all screen sizes)	Workpaper Measures	Baseline	Title 20 code minimum, 146.7 W on-mode power, 1 W sleep mode power, assumed 1014 in2 screen area	$2,571.15	-
		Measure	Energy Star 5.1 + 20%, 82.5 W on-mode power, assumed 1 W sleep mode power, 868 in2 screen area	$948.95	($1,622.20)
		Measure	Energy Star 5.1 + 35%, 67.1 W on-mode power, assumed 1 W sleep mode power, 868 in2 screen area	$559.82	($2,011.32)

3.2 Residential Lighting

For residential lighting measures, the study team leveraged related data collection and analysis activities scoped and initiated as part of WO28 (residential lighting impact evaluation) and WO13 (residential lighting market characterization) and ensure that the incremental cost estimates produced for the Measure Cost Study are internally consistent with related market characterization metrics, ex post impact estimates, and other evaluation results addressing the same market.

Appendix B provides a series of technical memoranda developed by the study team that provide detailed documentation of the data sources, data development process, modeling approaches, and modeling results.[8] The discussion presented below is synthesized from those memoranda.

3.2.1 Data Development Process

Table 3-7 shows the final data sources used for the unit price estimates for residential lighting measures. As the table shows, comprehensive shelf surveys of a large sample of retail lighting stores in California conducted for WO13 and WO28 was the primary data source used to estimate incremental costs for this study. In total, the shelf survey effort collected 23,775 price records from 184 retail lighting stores during fall 2011. Note that since the shelf survey sample was considered to be statistically representative of California retail lighting market, no validation data were assembled for residential lighting.

Table 3-7: Final Data Sources for Unit Price Estimates – Residential Lighting

Technology	Primary Price Data Source	Product Characteristics Source	Roll-up Weight Source	Price Validation Source
Incandescent (A-lamps, reflectors, globes, torpedoes)	Retail shelf surveys	Retail shelf surveys	POS data (ACNeilsen), IOU program data, Supplier interviews	None
CFL (A-lamps & twisters, reflectors, globes, torpedoes)				
LED (A-lamps, reflectors, globes, torpedoes)				

As part of the shelf survey effort, a host product attribute data relevant to the estimation of incremental cost due to efficiency were also collected. These attributes included store name and address, retail channel, model number, brand, lamp technology (incandescent, CFL, LED), base type, lamp style/shape, pack size, full price, discounted price, rate life (hrs), color temperature (degrees K), lumens, wattage, energy star, EISA compliance, dimmable, and 3-way functionality.

8 These memoranda were authored by DNV-GL, who conducted the residential lighting price data collection and analysis on a turnkey basis for this study.

The complete list of product attributes collected as part of the shelf survey effort is available in Appendix B.

Once the raw survey data was complied, the study team then conducted a thorough data cleaning process. This objective of this process was to ensure an analytic dataset that contained only general service, medium screw-based (MSB) lamps with complete and consistent data for each record. Specifically, this data cleaning process involved removing records for specialized lamps (e.g. night lights, bug lights, post lights, circline lamps, etc.), removing unusable observations (e.g. duplicates, inconsistent/unrealistic prices, very high wattage incandescents >200W, very high wattage CFLs >70W), and removing observations with incomplete price information.

The final tally of the cleaned sample was nearly 17,000 price observations, including 10,179 prices for incandescent lamps, 4,821 prices for CFL lamps, and 1,804 price observations for LED lamps. Frequency distributions of the final sample across retail channels, lamp type (e.g. A-lamp, globe, reflector, torpedo) as well as the frequency distribution of observed prices within these segmentations are available in Appendix B.

3.2.2 Market Assessment Findings

As part of the shelf survey effort, the WO13 team produced a stand-alone report that included a number of market assessment findings, as well as a dedicated LED market characterization study.[9,10] Among the key market assessment findings from those reports were:

- LED penetration in retail stores increased between 2008 and fall 2011 (more than one third of stores carried LEDs in 2008-2009 and more than half carried LEDs in fall 2011), whereas the penetration of "advanced" CFLs in stores remained relatively constant at close to 100 percent.[11]
- The stocking of advanced and non-advanced lamps in large home improvement stores more closely mirrored the proportions in non-big box stores than in the other big box channels, with nearly 90 percent of the lamps in these stores comprised of non-advanced lamps (primarily incandescent/halogens). In mass merchandise stores, advanced lamps represented more than one third of all lamps observed and in membership clubs, nearly half of all lamps (primarily advanced CFLs in both cases).
- In terms of the proportion of all lamps stocked within each channel, membership clubs stocked by far the highest proportion of LEDs compared to other channels (LEDs

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9 The final report from fall 2011 shelf survey is available at: http://www.energydataweb.com/cpucFiles/92/CaliforniaLightingRetailStoreShelfSurveyReport_3.pdf

10 The final report from the LED market characterization study is available at: http://www.energydataweb.com/cpucFiles/92/LEDMarketCharacterization_1.pdf

11 "Advanced" CFLs were defined as >30W, dimmable, 3-way, globes, and reflectors.

represented more than 10 percent of all lamps within membership clubs compared to 0-2 percent of all lamps within other channels).

- Only a little more than one third of all high-brightness general purpose A-lamps (1490−2600 lumens) were EISA-compliant across all stores in the fall 2011 sample. The phase-out of high-brightness general purpose A-lamps began on January 1, 2011 in California per AB 1109 legislation.
- Approximately one-tenth of all medium high-brightness (1050−1489 lumens) general purpose A-lamps were EISA-compliant across all stores in the fall 2011 sample. The phase-out of medium high-brightness general purpose A-lamps did not begin until January 1, 2012 in California per AB 1109 legislation (i.e., after the conclusion of this field research).
- On average, across all channels, there are almost twice as many non-compliant high-brightness lamps and more than eight times as many non-compliant medium high-brightness lamps per store as EISA-compliant lamps in those respective categories.
- Membership stores in the fall 2011 sample stocked the highest average number of EISA-compliant high-brightness A-lamps (nearly 80 per store) and had the highest proportion of EISA-compliant high-brightness A-lamps (100 percent).
- Discount stores represented the only channel from the fall 2011 sample that did not stock EISA-compliant high-brightness bulbs.

3.2.3 Modeling Process

Given the size of the price sample developed from the shelf survey data, the lamp price analysis was segmented by lamp technology (incandescent, CFL, and LED) and further by lamp shape (A-lamp/twister, reflector, globe, and torpedo) in order to account for the very different materials applications, costs, and features (e.g. color temperature, lumen output) associated with each. The study team thus developed individual hedonic price models for each of lamp technology/shape combinations (12 models total).

One of the unique (and difficult) analytic issues involved in estimating the average price of MSB lamps (compared to nearly all in-scope measures and technologies) is the multitude of retail delivery channels for such products, as they can be purchased at grocery stores, drug stores, hardware stores, home improvement stores, mass merchandise stores, and membership clubs. Each of these retail channels has different levels of purchasing power and pricing practices. To account for this, the study team specified retail delivery channel as an independent (categorical) variable within each of their hedonic pricing models. It should be noted that the model specifications initially included discount stores as a retail channel category. However, these specifications produced counter-intuitive results, which the study team believed resulted from the lack of price variation for lamps carried in that channel. To resolve this issue, the study team excluded discount stores as a retail channel category from their final model specifications.

When visually examining the shelf survey data, the team noted that MSB lamps from nationally-recognized brands tend to have higher prices than other brands, as had been observed for consumer appliances. However, rather than specifying each brand as an independent variable, the study team developed a "national brand" binary variable to capture the average price impact of well-known brands that are not exclusive to a particular store, chain, or channel. "National brands" included Feit, General Electric, Philips, Sylvania, and Westinghouse.[12]

Finally, when examining the relationship between lamp wattage and prices, the study team noted that the relationship did not appear to always be linear, with sometimes offsetting factors (e.g. higher prices for very low wattage incandescents, which are niche products). The team therefore specified the "watts" variable in their hedonic models as a spline variable in order to approximate this non-linear relationship. Spline variables allow a linear model to approximate a non-linear response. In this model, the two watt coefficients (e.g. "watts over 30" and "watts over 70" for incandescent A-lamps shown in Table 3-8 below) are additive. The interpretation is that the price of an incandescent lamp begins to increase linearly with watts when watts are greater than 30. The price then increases linearly with wattage until reaching 70 watts, above which price increases at a different rate.

12 Indeed, there are roughly 100 unique brands of incandescent, CFL, and LED lamps in the latest RMST POS sample, which indicates a uniquely high level of brand diversity compared to all other technologies and products within the scope of this study.

Table 3-8: Hedonic Price Model Results for Residential Lighting

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
Incandescent A-Lamp	Channel	Categorical	Home Improvement	0.00	.	.	0.036	0.237	N observations
			Drug Store	0.99	14.91	0.066	0.096		2,946
			Grocery	0.25	3.09	0.081	0.151		N unit sales
			Hardware	0.42	7.15	0.059	0.140		Unknown
			Mass Merchandise	0.13	2.03	0.062	0.356		R2
			Membership Club	0.42	0.89	0.473	0.000		0.580
	EISA	Binary	Yes	0.33	4.02	0.083	N/A	0.334	Intercept
			No	0.00	.	.	N/A	0.000	2.132
	Package size: 2 or more	Binary	Yes	-1.69	-21.56	0.078	0.919	-1.551	MAE
			No	0.00	.	.	0.081		0.660
	Package size: 3 or more	Binary	Yes	-1.16	-20.36	0.057	0.789	-0.912	Contr. Markup
			No	0.00	.	.	0.211		N/A
	Three-way	Binary	Yes	0.46	4.90	0.094	N/A	0.462	
			No	0.00	.	.	N/A	0.000	
	National brand	Binary	Yes	0.83	11.17	0.075	0.718	0.599	
			No	0.00	.	.	0.282		
	Expected Life (10e3 hrs)	Continuous	.6-15	0.20	6.63	0.030	N/A	0.199	
	Watts over 30	Continuous	0 - 120	0.01	5.16	0.002	N/A	0.009	
	Watts over 75	Binary	0 - 75	-0.01	-3.21	0.003	N/A	-0.009	
Incandescent Reflector	Channel	Categorical	Home Improvement	0.00	.	.	0.105	0.388	N observations
			Drug Store	2.60	13.24	0.197	0.063		2,172
			Grocery	0.89	2.92	0.305	0.325		N unit sales
			Hardware	1.48	12.50	0.118	0.087		Unknown
			Mass Merchandise	-0.18	-1.28	0.141	0.179		R2
			Membership Club	-1.10	-0.72	1.533	0.146		0.470
	Package size: 2 or more	Binary	Yes	-2.32	-15.83	0.147	0.338	-0.787	Intercept
			No	0.00	.	.	0.662		3.984
	Package size: 3 or more	Binary	Yes	-1.85	-9.35	0.198	0.119	-0.220	MAE
			No	0.00	.	.	0.881		1.649
	National brand	Binary	Yes	1.57	9.49	0.166	0.628	0.988	Contr. Markup
			No	0.00	.	.	0.372		N/A
	Expected Life (10e3 hrs)	Continuous	.75-8	0.59	12.32	0.048	N/A	0.591	
	Watts	Continuous	12-150	0.01	4.23	0.003	N/A	0.010	

Table 3-8: Hedonic Price Model Results for Residential Lighting (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	**Type**	**Values**	**Coefficient**	**t-stat**	**Standard Error**	**Roll-up Wts**	**Wtd Coefficient**	
Incandescent Globe	Channel	Categorical	Home Improvement	0.00	.	.	0.043	0.301	N observations
			Drug Store	0.90	9.63	0.094	0.060		4,279
			Grocery	0.15	1.30	0.117	0.292		N unit sales
			Hardware	0.51	7.03	0.072	0.232		Unknown
			Mass Merchandise	0.23	2.84	0.080	0.373		R2
	Package size: 2 or more	Binary	Yes	-2.50	-35.73	0.070	0.290	-0.723	0.620
			No	0.00	.	.	0.710		Intercept
	Package size: 3 or more	Binary	Yes	-1.46	-20.01	0.073	0.012	-0.018	2.465
			No	0.00	.	.	0.988		MAE
	National brand	Binary	Yes	0.64	6.60	0.097	0.665	0.424	1.203
			No	0.00	.	.	0.335		Contr. Markup
	Expected Life (10e3 hrs)	Continuous	0.75-15	0.97	34.47	0.028	N/A	0.967	N/A
	Watts	Continuous	3-150	0.01	7.77	0.001	N/A	0.009	
	Watts < 35	Binary	Yes	-1.27	-11.88	0.107	N/A	-1.275	
			No	0.00	.	.	N/A	0.000	
Incandescent Torpedo	Channel	Categorical	Home Improvement	0.00	.	.	0.160	0.250	N observations
			Hardware	0.30	2.89	0.010	0.840		141
	Package size: 2 or more	Binary	Yes	-2.56	-21.35	0.120	0.959	-2.454	N unit sales
			No	0.00	.	.	0.041		Unknown
	Expected Life (10e3 hrs)	Continuous	1.095-5	0.26	3.97	0.065	N/A	0.257	R2
	Watts	Continuous	3-150	0.00	-0.19	0.003	N/A	0.000	0.854
									Intercept
									3.743
									MAE
									0.367
									Contr. Markup
									N/A

Table 3-8: Hedonic Price Model Results for Residential Lighting (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	**Type**	**Values**	**Coefficient**	**t-stat**	**Standard Error**	**Roll-up Wts**	**Wtd Coefficient**	
CFL A-Lamps and Twisters	Channel	Categorical	Home Improvement	0.00	.	.	0.105	-0.150	N observations
			Drug Store	1.22	11.58	0.105	0.063		2,865
			Grocery	-0.37	-2.60	0.144	0.325		N unit sales
			Hardware	1.13	11.46	0.099	0.087		Unknown
			Mass Merchandise	-0.30	-3.18	0.094	0.179		R2
			Membership Club	-1.02	-4.79	0.213	0.146		0.750
	A-lamp Indicator	Binary	Yes	1.84	18.16	0.101	N/A	1.841	Intercept
			No	0.00	.	.	N/A	0.000	3.043
	Package size: 2 or more	Binary	Yes	-1.81	-21.60	0.084	0.756	-1.365	MAE
			No	0.00	.	.	0.244		1.236
	Package size: 4 or more	Binary	Yes	-1.13	-11.08	0.102	0.425	-0.480	Contr. Markup
			No	0.00	.	.	0.575		N/A
	Three-way	Binary	Yes	6.75	35.65	0.189	N/A	6.751	
			No	0.00	.	.	N/A	0.000	
	Dimmable	Binary	Yes	5.81	42.95	0.135	N/A	5.805	
			No	0.00	.	.	N/A	0.000	
	National brand, no utility discount	Binary	Yes	1.11	14.52	0.077	0.473	0.527	
			No	0.00	.	.	0.527		
	Utility discount, A-Lamp	Binary	Yes	-3.52	-5.40	0.651	N/A	-3.515	
			No	0.00	.	.	N/A	0.000	
	Utility discount, Twister	Binary	Yes	-1.80	-7.34	0.246	N/A	-1.804	
			No	0.00	.	.	N/A	0.000	
	Expected Life (10e3 hrs)	Continuous	1-15	0.06	3.54	0.017	N/A	0.062	
	Watts	Continuous	4-55	0.07	10.05	0.007	N/A	0.067	
	Watts over 25	Continuous	0-30	0.09	4.69	0.020	N/A	0.094	

Table 3-8: Hedonic Price Model Results for Residential Lighting (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
CFL Reflector	Channel	Categorical	Home Improvement	0.00	.	.	0.242	0.227	N observations
			Drug Store	2.74	11.61	0.236	0.097		1,019
			Grocery	0.64	1.68	0.380	0.209		N unit sales
			Hardware	1.60	7.89	0.202	0.112		Unknown
			Mass Merchandise	0.10	0.50	0.204	0.190		R2
			Membership Club	-2.45	-7.26	0.338	0.151		0.700
	Package size: 2 or more	Binary	Yes	-2.79	-15.62	0.179	0.206	-0.576	Intercept
			No	0.00	.	.	0.794		5.028
	Dimmable	Binary	Yes	4.05	24.75	0.164	N/A	4.046	MAE
			No	0.00	.	.	N/A	0.000	1.583
	National brand	Binary	Yes	1.08	6.85	0.157	0.881	0.947	Contr. Markup
			No	0.00	.	.	0.119		N/A
	Utility discount	Binary	Yes	-3.04	-8.92	0.341	N/A	-3.040	
			No	0.00	.	.	N/A	0.000	
	Watts	Continuous	5-26	0.15	10.98	0.013	N/A	0.147	
CFL Globe	Channel	Categorical	Home Improvement	0.00	.	.	0.242	-0.655	N observations
			Drug Store	1.00	3.44	0.292	0.097		298
			Grocery	0.03	0.07	0.512	0.209		N unit sales
			Hardware	0.54	2.04	0.263	0.112		Unknown
			Mass Merchandise	-1.53	-6.93	0.221	0.190		R2
			Membership Club	-3.50	-8.90	0.394	0.151		0.766
	Package size: 2 or more	Binary	Yes	-1.72	-6.14	0.280	0.174	-0.299	Intercept
			No	0.00	.	.	0.826		7.315
	Package size: 3 or more	Binary	Yes	-0.61	-1.69	0.363	0.001	-0.001	MAE
			No	0.00	.	.	0.999		0.931
	National brand	Binary	Yes	1.36	5.30	0.256	0.927	1.258	Contr. Markup
			No	0.00	.	.	0.073		N/A
	Utility discount	Binary	Yes	-1.25	-2.87	0.435	N/A	-1.248	
			No	0.00	.	.	N/A	0.000	
	Watts	Continuous	9-23	-0.03	-0.67	0.039	N/A	-0.026	

Table 3-8: Hedonic Price Model Results for Residential Lighting (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
CFL Torpedo	Channel	Categorical	Home Improvement	0.00	.	.	0.285	0.410	N observations
			Drug Store	1.75	3.66	0.479	0.114		106
			Grocery	1.43	1.70	0.841	0.246		N unit sales
			Hardware	0.79	1.61	0.491	0.132		Unknown
			Mass Merchandise	-1.10	-1.82	0.603	0.223		R2
	Package size: 2 or more	Binary	Yes	-2.01	-3.68	0.546	0.059	-0.119	0.620
			No	0.00	.	.	0.941		Intercept
	Package size: 3 or more	Binary	Yes	-0.86	-1.15	0.747	0.000	0.000	4.920
			No	0.00	.	.	1.000		MAE
	Expected Life (10e3 hrs)	Continuous	2-25	0.08	1.82	0.042	N/A	0.077	1.084
	Watts	Continuous	5-15	0.21	2.61	0.079	N/A	0.206	Contr. Markup
									N/A
LED A-Lamp	Channel	Categorical	Home Improvement	0.00	.	.	0.480	1.261	N observations
			Grocery	2.43	1.65	1.473	0.520		200
			Hardware	8.30	4.82	1.724	N/A		N unit sales
			Mass Merchandise	-0.05	-0.04	1.232	N/A		Unknown
			Membership Club	-8.31	-8.22	1.011	N/A		R2
	National Brand	Binary	Yes	4.50	5.99	0.753	0.956	4.304	0.750
			No	0.00	.	.	0.044		Intercept
	Utility discount	Binary	Yes	-5.56	-2.17	2.560	N/A	-5.559	1.981
			No	0.00	.	.	N/A	0.000	MAE
	Energy Star and no utility discount	Binary	Yes	2.37	2.55	0.929	N/A	2.372	3.228
			No	0.00	.	.	N/A	0.000	Contr. Markup
	Watts	Continuous	1.1-13	2.04	18.78	0.109	N/A	2.042	N/A

Table 3-8: Hedonic Price Model Results for Residential Lighting (continued)

Technology	Model Variables: Name	Type	Values	Model Results: Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	Model Stats
LED Reflector	Channel	Categorical	Home Improvement	0.00	.	.	0.480	1.485	N observations
			Hardware	2.86	1.77	1.613	0.520		438
			Mass Merchandise	-6.38	-2.30	2.770	N/A		N unit sales
			Membership Club	-12.40	-8.03	1.544	N/A		Unknown
	National Brand	Binary	Yes	6.84	7.83	0.874	0.194	1.326	R2
			No	0.00	.	.	0.806		0.470
	Utility discount	Binary	Yes	-6.34	-3.27	1.938	N/A	-6.337	Intercept
			No	0.00	.	.	N/A	0.000	16.594
	Energy Star and no utility discount	Binary	Yes	7.61	7.14	1.065	N/A	7.608	MAE
			No	0.00	.	.	N/A	0.000	6.164
	Watts	Continuous	0.9-24	1.41	16.14	0.087	N/A	1.406	Contr. Markup
									N/A
LED Globe	Channel	Categorical	Home Improvement	0.00	.	.	0.480	2.536	N observations
			Hardware	4.88	4.40	1.110	0.520		104
			Mass Merchandise	-4.70	-4.09	1.149	N/A		N unit sales
			Membership Club	-3.58	-4.01	0.892	N/A		Unknown
	National Brand	Binary	Yes	6.64	9.26	0.717	0.260	1.726	R2
			No	0.00	.	.	0.740		0.900
	Energy Star	Binary	Yes	3.97	1.74	2.279	N/A	3.970	Intercept
			No	0.00	.	.	N/A	0.000	2.337
	Expected Life (10e3 hrs)	Continuous	0.012-0.05	0.07	2.63	0.028	N/A	0.074	MAE
	Watts	Continuous	1-10	2.30	14.80	0.156	N/A	2.302	2.233
									Contr. Markup
									N/A
LED Torpedo	Channel	Categorical	Home Improvement	0.00	.	.	0.480	1.631	N observations
			Drug Store	3.14	2.26	1.385	0.520		49
			Grocery	-0.48	-0.39	1.233	N/A		N unit sales
			Hardware	3.20	2.78	1.150	N/A		Unknown
			Mass Merchandise	-1.42	-1.41	1.003	N/A		R2
	National Brand	Binary	Yes	5.05	3.17	1.592	0.137	0.689	0.450
			No	0.00	.	.	0.863		Intercept
	Watts	Continuous	1.2-4	2.97	4.33	0.686	N/A	2.972	1.863
									MAE
									1.545
									Contr. Markup
									N/A

3.2.4 Roll-up Weights

As the results in Table 3-8 above show, retail channel has a statistically significant impact on the average price of incandescent, CFL, and LED lamps. However, since retail channel has no relationship to energy performance, the study team developed volume share estimates for each retail channel in order to roll-up those coefficients into a market average value. In the case of MSB lamps, however, no single comprehensive source of volume shares across these different retail channels exists. Estimating those retail channel shares therefore requires combining data and market share estimates from a wide variety of sources, and much of the study team's effort was therefore dedicated to developing estimates of retail channel weights. The complete details of the methodology and data sources used by the study team to develop retail channel weights are provided in Appendix B.

In addition to retail channel, Table 3-8 shows that pack size and "national brand" also have statistically significant impact on the average price of incandescent and CFL lamps. The POS data assembled for WO23 (Residential Market Share Tracking) included fields for both pack size and brand for each record, as well as unit price and volume. The study team used this data directly to develop roll-up weights for the pack size and "national brand" coefficients.

3.2.5 Modeling Results and Findings

Because the energy efficiency "measure" for residential lighting is almost always the replacement of an existing light source (e.g. incandescent lamps) with a higher-efficacy light source (e.g. CFLs or LEDs), it is necessary to map the "equivalency" of lamps across technologies in order to estimate the associated incremental costs. The study team developed such a mapping using lumen output as the key metric to determine equivalent energy service across incandescent, CFL, and LED lamps of similar shapes. The complete details and results of the lumen equivalency mapping are provided in Appendix B.

Table 3-9 presents the incremental cost estimates for CFL and LED lamps.[13] For the sake of brevity, the table present results for an illustrative subset of all the specific CFL wattages currently defined in DEER and the IOU workpapers. Note that EISA-compliance and rated life are currently not included as parameters in DEER or IOU workpaper measures definitions, thus the incremental cost estimates shown in Table 3-9 are therefore associated with "example" measure definitions. A larger set of incremental cost estimates that cover a wider range of the specific CFL wattages specified in DEER and the IOU workpapers is provided in Appendix F.

As Table 3-9 shows, the average incremental cost for CFL A-lamp/twister lamps is estimated to be less than $2/lamp for lamps under 25 watts and over $4/lamp for higher wattage lamps. These

[13] The complete set of incremental cost estimates based on the measure definitions from READI v.1.0.4 "Draft Combined DEER 2011 and DEER 2014 plus IOU Ex Ante for the 2013-14 Cycle" is provided in Appendix F.

estimates represent a small decrease in incremental costs for these products compared to previous DEER estimates. For CFL reflectors and globes, the average incremental costs are estimated to be below $3/lamp, which represents a larger relative decrease from previous DEER estimates (>$8/lamp). For LEDs, the average incremental cost for all lamp shapes is still high relative to both incandescents and CFLs, ranging from $7/lamp for torpedoes to $24-$33/lamp for A-lamps and $40-50/lamps for reflectors.

Table 3-9: Incremental Equipment Price Estimates for Residential Lighting

Technology	Measure Source	Match Pair	Description	Modeled price	IMC
CFL A-Lamps and Twisters	Example Measures	Baseline	Incandescent A-Lamp, EISA, 1,500 hours, low brightness (40W)	$1.23	-
		Measure	CFL Twister, 10,000 hours, low brightness (10W)	$2.86	$1.63
		Baseline	Incandescent A-Lamp, EISA, 1,500 hours, medium brightness (60W)	$1.41	-
		Measure	CFL Twister, 10,000 hours, medium brightness (15W)	$3.19	$1.78
		Baseline	Incandescent A-Lamp, EISA, 1,500 hours, high brightness (90W)	$1.56	-
		Measure	CFL Twister, 10,000 hours, high brightness (25W)	$6.19	$4.63
CFL Reflectors	Example Measures	Baseline	Incandescent Reflector, 2,000 hours, medium brightness (60W)	$6.16	-
		Measure	CFL Reflector, medium brightness (15W)	$7.84	$1.68
		Baseline	Incandescent Reflector, 2,000 hours, high brightness (90W)	$6.47	-
		Measure	CFL Reflector, high brightness (25W)	$9.31	$2.84
CFL Globes	Example Measures	Baseline	Incandescent Globe, 2,000 hours, low brightness (40W)	$4.75	-
		Measure	CFL Globe (10W)	$7.36	$2.60
		Baseline	Incandescent Globe, 2,000 hours, medium brightness (60W)	$4.94	-
		Measure	CFL Globe (15W)	$7.23	$2.29
CFL Torpedoes	Example Measures	Baseline	Incandescent Torpedo, 2,000 hours	$2.05	-
		Measure	CFL Torpedo, 10,000 hours, low brightness (11W)	$8.24	$6.19
		Measure	CFL Torpedo, 10,000 hours, medium brightness (15W)	$9.07	$7.01
LED A-Lamp	Example Measures	Baseline	Incandescent A-Lamp, EISA, 1,500 hours, low brightness (40W)	$1.23	-
		Measure	LED A-Lamp, Energy Star, low brightness (9W)	$28.29	$27.07
		Baseline	CFL Twister, 10,000 hours, low brightness (10W)	$2.86	-
		Measure	LED A-Lamp, Energy Star, low brightness (9W)	$28.29	$25.44
		Baseline	Incandescent A-Lamp, EISA, 1,500 hours, medium brightness (60W)	$1.41	-
		Measure	LED A-Lamp, Energy Star, medium brightness (12W)	$34.42	$33.01
		Baseline	CFL Twister, 20,000 hours, medium brightness (15W)	$3.19	-
		Measure	LED A-Lamp, Energy Star, medium brightness (12W)	$34.42	$31.23
LED Reflector	Example Measures	Baseline	Incandescent Reflector, 2,000 hours, medium brightness (60W)	$6.16	-
		Measure	LED Reflector, Energy Star, medium brightness (15W)	$48.10	$41.94
		Baseline	CFL Reflector, medium brightness (15W)	$7.84	-
		Measure	LED Reflector, Energy Star, medium brightness (15W)	$48.10	$40.27
		Baseline	Incandescent Reflector, 2,000 hours, high brightness (90W)	$6.47	-
		Measure	LED Reflector, Energy Star, high brightness (22W)	$57.94	$51.47
		Baseline	CFL Reflector, high brightness (25W)	$9.31	-
		Measure	LED Reflector, Energy Star, high brightness (22W)	$57.94	$48.63
LED Globe	Example Measures	Baseline	Incandescent Globe, 2,000 hours, low brightness (40W)	$4.75	-
		Measure	LED Globe, Energy Star, 30,000 hours, low brightness (8W)	$31.21	$26.45
		Baseline	CFL Globe	$7.62	-
		Measure	LED Globe, Energy Star, 30,000 hours, low brightness (8W)	$31.21	$23.59
LED Torpedo	Example Measures	Baseline	Incandescent Torpedo, 2,000 hours	$2.05	-
		Measure	LED Torpedo, low brightness (4W)	$16.07	$14.02
		Baseline	CFL Torpedo, 10,000 hours, low brightness (11W)	$8.24	-
		Measure	LED Torpedo, low brightness (4W)	$16.07	$7.83

3.3 Residential HVAC, Water Heating, and Shell

3.3.1 Data Development

For room air conditioners (RAC), the study team acquired comprehensive POS data from the NPD Group. This dataset came populated with dozens of product characteristics for each record, along with the average, actual selling price in each of 11 previous quarters (Q1 2010 through Q2 2012).[14] Due the comprehensiveness of the NPD POS data, data development efforts for RAC were minimal and focused on refining the EER rating data. In the original NPD POS dataset, the energy efficiency ratio (EER) ratings were provided as ranges, rather than discrete values. In most cases, the "EER bins" were defined across 0.4 EER ranges, e.g. 9.0-9.4 EER, 9.5-9.9 EER, 10.0-10.4 EER. In order to enable a more robust analysis of the relationship between EER rating and price, the study team used product-specific cut sheets to look up and assign discrete EER ratings to each record wherever possible. In cases where model numbers were masked or product cut sheets were not available, the study team assigned the mid-point value.[15]

For all other in-scope residential HVAC, water heating, and shell measures, the study team collected unit price data at the distributor level. For split-system direct expansion (DX) air conditioners and heat pumps (HP), the study originally collected distributor prices only for outdoor condenser units. Based on that list of condenser units, the study team used AHRI's *Directory of Certified Product Performance* to identify the specific indoor coil units that produced specific system seasonal energy efficiency ratio (SEER) levels when paired with specific condenser units. The study team then collected unit price data for those specific indoor coil units. As a final step, the study team used the AHRI database to refine the system SEER ratings (i.e. adding a decimal place) for each matched pair of outdoor condenser/indoor coil units.

For gas furnaces and storage water heaters (gas and electric), the study team used the CEC's *Appliance Database* to backfill each price record with product attributes and cross-check the capacity and annual fuel utilization efficiency (AFUE) and energy factor (EF) ratings, respectively, included in the distributor price lists. For storage water heaters, the study team used product cut sheets to create and backfill a "power venting" variable. For whole house fans, tankless water heaters, heat pump water heaters (HPWH), batt insulation, and HVAC fan motors, all product attributes were backfilled using product-specific cut sheets. Note that for gas furnaces, storage water heaters, and HVAC fan motors, the study team strategically added to the original price sample multiple times in order to ensure that the overall price sample adequately represented the full range of capacities and efficiency levels specified in DEER and the IOU workpapers and the various possible combinations within.

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14 See Appendix A of the *Task 5 Report* for a complete list of the product attributes included in the NPD POS data.

15 For the >10.5 and <8.0 EER bins, the study team assigned values of 10.6 and 7.9, respectively, in cases where model numbers were masked or product cut sheets were not available.

Table 3-10 shows the final data sources used for the unit price estimates for residential HVAC, water heating, and shell measures. As the table shows, to validate the predicted unit prices for RAC, the study team used invoices from the CEC's C4A program, which covered roughly the same period (2010-2011) and included 399 invoices for RAC units. For whole house fans, gas furnaces, storage water heaters, tankless water heaters, HPWHs, and batt insulation, the study team used price lookups from online retailers and distributors to validate predicted prices.[16] For split-system DX and HP, the study team validated predicted prices using previous DEER estimates and a small sample of artificial project bids.[17]

Table 3-10: Final Data Sources for Unit Price Estimates – Residential HVAC, Water Heating, and Shell

<table>
<tr><th>Technology</th><th>Primary Price Data Source</th><th>Product Characteristics Source</th><th>Roll-up Weight Source</th><th>Price Validation Source</th></tr>
<tr><td>Room AC (cooling only, window units only)</td><td>NPD POS data</td><td>NPD, product cut sheets</td><td>NPD</td><td>C4A</td></tr>
<tr><td>Whole House Fans</td><td rowspan="10">Distributor price lists</td><td rowspan="2">Product cut sheets</td><td>N/A</td><td rowspan="2">Online retailer price lookups</td></tr>
<tr><td>Gas Furnaces (residential)</td><td>CLASS</td></tr>
<tr><td>Split-System HP (residential and commercial)</td><td>AHRI</td><td rowspan="2">CMST</td><td rowspan="2">DEER, artificial project bids</td></tr>
<tr><td>Split-System DX (residential and commercial)</td><td>AHRI</td></tr>
<tr><td>Residential HVAC fan motors</td><td rowspan="6">Product cut sheets</td><td>Price sample</td><td rowspan="6">Online retailer price lookups</td></tr>
<tr><td>Small Storage Gas WH
(<= 75,000 BtuH and EF rated)</td><td rowspan="3">CLASS</td></tr>
<tr><td>Electric Storage WH</td></tr>
<tr><td>Tankless WH</td></tr>
<tr><td>Heat Pump Water Heaters</td><td>N/A</td></tr>
<tr><td>Batt Insulation</td><td>Price sample</td></tr>
</table>

3.3.2 Market Assessment Findings

In developing the unit price sample for gas storage water heaters, the study team found that the availability of baseline efficiency units (generally EF=0.60 and below) from equipment distributors was remarkably low compared to higher efficiency units. When investigating this dynamic, distributors indicated that standard practice among contractors in California is to

[16] Including but not limited to Grainger, Home Depot, Lowe's, Pex Supply, and a host of smaller, specialty distributors.

[17] See Sections 4.1 and 4.3 for additional discussion of the artificial bids developed and implemented by the study team.

specify and install above-code gas storage water heaters, usually with an EF rating of 0.62. Indeed, the mean EF rating in the final price sample for gas storage water heaters is 0.63. While this evidence is largely anecdotal and does not constitute anything approaching a complete assessment of energy efficiency market shares for storage water heaters, this finding indicates a level of market transformation that, if proven to be true, would have a direct impact on program design for gas storage water heaters going forward and thus warrants further investigation.

Conversely, when developing the unit price sample for residential HVAC motors, the study team found that the availability of electronically commutated (ECM) and X13 HVAC motors suitable as drop-in replacements for existing permanent split-capacitor (PSC) or shaded-pole motors was extremely limited. Upon further investigation, it appears that the vast majority of ECM and X13 fan motors appear to be produced for the OEM market (as part of high-efficiency furnace, heat pump, or central air conditioning systems). Indeed, the study team could only identify four families of ECM motors suitable as drop-in replacements for existing PSC or shaded-pole fan motors that are readily available in the market.[18]

3.3.3 Modeling Process

The overriding analytic issue for RAC was accounting for price changes over time (e.g. removing the influence of inflation) and seasonal pricing. To transform the time series data from nominal to real prices, the study team applied the Consumer Price Index (CPI).[19] The team then estimated time fixed effects (e.g. seasonal pricing and real price trends) through specification of dummy variables for each quarter.

For split-system HPs, the study team attempted to isolate the incremental cost associated with SEER, EER, and HSPF ratings simultaneously. However, these three variables are very highly collinear. Since SEER is the key energy performance metric currently specified in DEER and the IOU workpapers, the study team used SEER as the sole efficiency metric in the split-system HP models. Apart from these issues, however, the modeling process for residential HVAC, water heating, and shell measures was straightforward and produced intuitive results, as shown in Table 3-11.

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18 Rescue Ecotech series from US Motors, Comfort Select FB series from Century Motors, Evergreen IM series from Genteq (General Electric), and Azure Series from Mars Motors.

19 Department Store Inventory Price Index for Major Appliances (series ID LIUR0000SL00019). Note that CPI is a monthly index, while the NPD POS data were quarterly. The study team used the CPI values from the first month of each quarter to transform the quarterly average prices to real prices, i.e. Jan 2011 = Q1 2011.

Table 3-11: Hedonic Price Model Results for Residential HVAC, Water Heating, and Shell

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
Room AC (cooling only, window units only)	Energy Star	Binary	Yes	-10.25	-1.10	9.290	N/A	-10.250	N observations
			No	0.00	--	--	N/A	0.000	638
	Capacity (btuh)	Continuous	5,500 - 29,000	0.02	32.22	0.001	N/A	0.023	N unit sales
	Chassis type	Categorical	Not Specified	0.00	--	--	0.043	1.388	161,424
			Fixed	0.81	0.11	7.590	0.929		R2
			Slide-out	22.60	2.10	10.770	0.028		0.880
	Quarter	Categorical	1	0.00	--	--	0.021	-6.279	Intercept
			2	-3.04	-0.34	9.030	0.552		-269.400
			3	-10.93	-1.20	9.100	0.420		MAE
			4	-1.12	-0.06	18.760	0.007		
	Air direction control	Categorical	2-way	0.00	--	--	0.485	16.215	Contr. Markup
			4-way	26.10	4.67	5.590	0.137		N/A
			8-way	33.45	7.26	4.610	0.378		
	EER	Continuous	8.7 - 11	27.54	2.73	10.080	N/A	27.540	
Whole House Fans	CFM	Continuous	600-6418	0.11	5.68	0.018	N/A	0.106	N observations
	Number of fans	Continuous	1,2,4	118.61	2.90	40.950	N/A	2.900	25
	Industrial grade	Binary	yes	570.21	6.74	84.590	0.880	501.785	N unit sales
			no	0.00	--	--	0.120		Unknown
									R2
									0.789
									Intercept
									157.710
									MAE
									101.090
									Contr. Markup
									0.20

Table 3-11: Hedonic Price Model Results for Residential HVAC, Water Heating, and Shell (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
Gas Furnaces (residential)	AFUE	Continuous	0.78-0.96	2056.06	13.74	149.635	N/A	2056.064	N observations
	Capacity (Btuh)	Continuous	32,000-155,000	0.00	6.88	0.000	N/A	0.003	176
	Variable Speed Blower	Categorical	with variable speed	319.96	11.83	27.038	0.284	90.899	N unit sales
			w/o variable speed	0.00	--	--	0.716		Unknown
	Manufacturer	Categorical	Bryant	-12.28	-0.36	34.063	0.000	10.202	R2
			Day and Night	-171.26	-2.92	58.705	0.015		0.794
			Goodman	36.54	1.30	28.212	0.061		Intercept
			Ruud	0.00	--	--	0.000		-1364.637
									MAE
									94.480
									Contr. Markup
									0.32
Split-System HP (residential and commercial)	Cooling Capacity (BtuH)	Continuous	17400-59000	0.04	7.37	0.006	N/A	0.041	N observations
	SEER	Continuous	13-20.5	456.91	9.54	47.880	N/A	456.908	78
	Brand	Categorical	Carrier	1558.74	8.09	192.668	0.319	533.053	N unit sales
			Day & Night	-198.05	-1.00	197.379	0.000		Unknown
			Bryant	675.77	2.61	259.309	0.053		R2
			Goodman	0.00	.	.	0.058		0.827
									Intercept
									-6472.086
									MAE
									473.613
									Contr. Markup
									0.20

Table 3-11: Hedonic Price Model Results for Residential HVAC, Water Heating, and Shell (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
Split-System DX (residential and commercial)	Cooling Capacity (BtuH)	Continuous	17000-58000	0.02	17.65	0.001	N/A	0.023	N observations
	SEER	Continuous	13-18.5	230.32	16.86	13.660	N/A	230.317	83
	Brand	Categorical	Bryant	-39.08	-0.99	39.534	0.265	-2.081	N unit sales
			Day and Night	27.48	0.73	37.799	0.301		Unknown
			Goodman	0.00	.	.	0.434		R2
									0.893
									Intercept
									-2762.950
									MAE
									106.603
									Contr. Markup
									0.20
Residential HVAC Fan Motors	Motor Type	Categorical	PSC	0.00	.	.	N/A	0.000	N observations
			High-efficiency PSC	117.02	4.70	24.91	N/A	117.020	93
			ECM/X13	123.15	4.91	25.09	N/A	123.150	N unit sales
	Horsepower	Continuous	0.167-1 (1/6 - 1 hp)	158.75	4.10	38.72	N/A	158.750	Unknown
	Reversible	Binary	Yes	-96.81	4.12	23.48	0.688	-66.622	R2
			No	0.00	.	.	0.312		0.510
	Input Voltage > 230	Binary	Yes	100.43	1.61	62.19	0.022	2.160	Intercept
			No	0.00	.	.	0.978		276.730
	Number of Speeds	Continuous	1-5	-23.79	2.26	10.55	N/A	-23.790	MAE
									60.34
									Contr. Markup
									0.20

Table 3-11: Hedonic Price Model Results for Residential HVAC, Water Heating, and Shell (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
Batt Insulation	R-Value	Continuous	11-38	0.01	7.48	0.002	N/A	0.014	N observations
	High Density	Binary	Yes	0.12	4.91	0.024	0.220	0.025	41
			No	0.00	--	--	0.780		N unit sales
	Kraft Faced	Binary	Yes	0.05	1.72	0.028	0.122	0.006	Unknown
			No	0.00	--	--	0.878		R2
	Brand	Categorical	CertainTeed	0.07	4.05	0.017	0.512	0.036	0.886
			Knauf	0.00	--	--	0.488		Intercept
	Width (Inches)	Continuous	15-24	0.00	0.35	0.003	N/A	0.001	-0.037
	Coverage (Sq Ft/bag)	Continuous	31.998-256	0.00	-0.24	0.000	N/A	0.000	MAE
									0.030
									Contr. Markup
									0.20
Small Storage Gas WH (<= 75,000 BtuH and EF rated)	Energy Factor	Continuous	0.58-0.7	2332.51	2.32	1005.121	N/A	2332.506	N observations
	Rated Volume (gallons)	Continuous	30-65	9.07	2.08	4.361	N/A	9.068	54
	Forced Draft	Binary	Yes	473.20	5.17	91.471	0.315	148.972	N unit sales
			No	0.00	--	--	0.685		Unknown
	Manufacturer	Categorical	AO Smith	-163.91	-0.95	173.271	0.000	0.000	R2
			Bradford-White Co.	0.00	--	--	0.000		0.691
			Rheem	4.63	0.05	100.947	0.000		Intercept
			State Industries	-33.31	-0.35	94.795	0.000		-1247.538
									MAE
									153.534
									Contr. Markup
									0.15

Table 3-11: Hedonic Price Model Results for Residential HVAC, Water Heating, and Shell (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
Electric Storage WH	Energy Factor	Continuous	0.86-0.95	8916.78	5.19	1716.466	N/A	8916.779	N observations
	Rated Volume	Continuous	30-80	14.09	6.70	2.102	N/A	14.086	32
	Manufacturer	Categorical	A.O. Smith	23.95	0.44	55.040	0.000	8.768	N unit sales
			Bradford-White Co.	0.00	--	--	0.000		Unknown
			Rheem	113.72	2.11	53.949	0.077		R2
			State Industries	-12.29	-0.24	51.728	0.000		0.755
									Intercept
									-8409.619
									MAE
									71.264
									Contr. Markup
									0.15
Tankless WH	Thermal Efficiency	Continuous	82 - 92 (.82-.92)	13.98	2.97	4.710	N/A	13.980	N observations
	Capacity (Mbtu)	Continuous	120-250	5.55	8.47	0.655	N/A	5.550	32
	Rheem	Binary	Yes	-119.99	-2.60	46.150	0.313	-37.497	N unit sales
			No	0.00	--	--	0.688		Unknown
									R2
									0.768
									Intercept
									-1300.220
									MAE
									88.090
									Contr. Markup
									0.25
Heat Pump WH	Storage Volume (gallons)	Continuous	40 - 80	23.23	6.47	639.710	N/A	23.230	N observations
	Input KW	Continuous	2.2 - 5.5	-230.48	3.17	72.760	N/A	-230.480	25
	Energy Factor	Continuous	2 - 2.51	-782.21	2.52	310.080	N/A	-782.210	N unit sales
	Volt 230	Binary	yes	361.35	2.30	157.070	N/A	361.350	N/A
			no	0.00	--	--	N/A	0.000	R2
									0.777
									Intercept
									2955.870
									MAE
									110.110
									Contr. Markup
									0.00

3.3.4 Roll-up Weights

The study team developed roll-up weights for several variables that had statistically significant price effects but no relationship to energy performance and not present in DEER/IOU workpaper measure definitions. For RAC, these variables included quarter, chassis type, and air direction control. For gas furnaces, storage water heaters, split-system HP and DX, this included brand.

In the case of RAC, the NPD POS data included volume shares for each record, and the study team used this data directly to develop market shares and roll-up weights for all of the variables above. In the case of gas furnaces and storage water heaters, the study team leveraged recent on-site survey data from CLASS to develop brand shares of equipment installed since 2006. For split-system HP and DX, the study team leveraged recent on-site survey data from CMST to develop brand shares of equipment installed since 2009.

Note that for split-system HPs, the rolled-up coefficient for brand is quite large ($500) and is driven primarily by the brand effect for Carrier units (which have the largest market share). However, this result likely captures other price effects not specified in the model (e.g. distributor pricing practices) should not be viewed as a pure reflection of the premium consumers pay for Carrier systems.

3.3.5 Modeling Results and Findings

Table 3-12 presents the study team's estimates of incremental equipment prices for residential HVAC, water heating, and shell measures.[20]

As the table shows, the study team found statistically significant but relatively low incremental costs for high-efficiency RAC units – averaging roughly $16 per unit. These incremental cost estimates are significantly smaller than the current IOU workpaper values ($50 per unit). The study team validated predicted prices from the RAC model against a larger sample of C4A invoices, with predicted prices coming within an average of 5 percent of actual prices.

For whole-house fans, gas furnaces, storage water heaters (gas and electric), and tankless water heaters, the study team found statistically significant incremental costs for higher efficiency units. For all these technologies, predicted prices validated well compared to small samples of online retail price lookups, generally falling within 5-10 percent of actual prices. For furnaces, both predicted prices and incremental costs are fairly consistent with current IOU workpaper estimates for 90 and 92 AFUE units ($335-$380/unit). For lower AFUE units (81 AFUE), the study team's incremental cost estimates are much lower ($80 vs. $300/unit) than IOU workpaper

[20] The complete set of incremental cost estimates based on the measure definitions from READI v.1.0.4 "Draft Combined DEER 2011 and DEER 2014 plus IOU Ex Ante for the 2013-14 Cycle" is provided in Appendix F.

estimates, whereas for higher AFUE units (96 AFUE) the study team's incremental cost estimates are much higher ($900 vs. $500/unit).

For storage water heaters, predicted prices and incremental cost estimates are consistently higher than current DEER estimates. While it is difficult determine exact the exact source of these differences, the fact that the predicted prices (across a range of capacities and efficiencies) validate well against "out of sample" prices lends credence to the study team's estimates. For tankless water heaters, predicted prices and incremental cost estimates are generally consistent with current DEER estimates, though the costs are difficult to compare directly because the DEER measure definitions only specify large, discrete capacity and efficiency ranges.

For split-system HPs, predicted prices generally benchmark well when compared to a small sample of artificial project bids and previous DEER estimates. For split-system DX, predicted prices are systematically lower compared to current and previous DEER estimates by 10-30 percent. Similarly for incremental costs, the study team's estimates for split-system DX are consistently lower than current DEER estimates by 10-30 percent.

For residential HVAC fan motors, predicted prices compare well to a small sample of online retail price lookups. However, the predicted price for ECM motors is significantly higher than current IOU workpaper estimates ($352 vs. $198 for a 0.5 hp unit). It should be noted, however, that the IOU workpaper estimates were based on price quotes from one distributor (EFI) that no longer carries that line of ECM motors (Concept 3).

For batt insulation, predicted prices are consistently lower when compared to online retail price lookups and previous DEER estimates by roughly 50 percent. Based on conversations with DEG, the study team believes this result reflects a lower average cost to final customers when procuring batt insulation via contractors compared to direct retail purchase due to significant bulk purchase discounts garnered by contractors. However, this result merits further vetting and investigation.

Table 3-12: Incremental Equipment Price Estimates for Residential HVAC, Water Heating, and Shell

Technology	Measure Source	Match Pair	Description	Modeled Price	IMC
Room AC (cooling only, window units only)	Workpaper Measures	Baseline	Non-Energy Star with louvered sides 6,000 btuh 9.7 EER	$147.03	-
		Measure	Energy Star with louvered sides 6,000 btuh 10.7 EER	$164.33	$17.29
		Baseline	Non-Energy Star without louvered sides 6,000 btuh 9.0 EER	$127.75	-
		Measure	Energy Star without louvered sides 6,000 btuh 9.9 EER	$142.29	$14.54
		Baseline	Non-Energy Star with louvered sides 8,000 btuh 9.8 EER	$195.79	-
		Measure	Energy Star with louvered sides 8,000 btuh 10.8 EER	$213.08	$17.29
		Baseline	Non-Energy Star with louvered sides 14,000 btuh 9.7 EER	$331.03	-
		Measure	Energy Star with louvered sides 14,000 btuh 10.7 EER	$348.33	$17.29
		Baseline	Non-Energy Star with louvered sides 20,000 btuh 8.5 EER	$435.98	-
		Measure	Energy Star with louvered sides 20,000 btuh 9.4 EER	$450.52	$14.54
Whole House Fans	Example Measures	Baseline	Absence of whole house fan	-	-
		Measure	Whole house fan 2500 CFM, 1 fan, industrial grade	$1,333.84	$1,333.84
		Measure	Whole house fan 1600 CFM, 1 fan	$535.10	$535.10
		Measure	Whole house fan 2500 CFM, 1 fan	$649.58	$649.58
		Measure	Whole house fan 4500 CFM, 1 fan	$903.98	$903.98
		Measure	Whole house fan 1150 CFM, 2 fans	$620.20	$620.20
Gas Furnaces (residential)	DEER Measures	Baseline	78 AFUE (1.242 HIR) Furnace assumed 60 kBtuh capacity without variable speed blower	$586.23	-
		Measure	Furnace Upgrade to 81% AFUE assumed 60 kBtuh capacity without variable speed blower	$667.65	$81.42
		Baseline	78 AFUE (1.242 HIR) Furnace assumed 90 kBtuh capacity without variable speed blower	$714.81	-
		Measure	High Efficiency Furnace 90 AFUE(1.11 HIR) assumed 90 kBtuh capacity without variable speed blower	$1,040.49	$325.68
		Baseline	78 AFUE (1.242 HIR) Furnace assumed 120 kBtuh capacity without variable speed blower	$843.39	-
		Measure	High Efficiency Furnace 92 AFUE(1.08 HIR) assumed 120 kBtuh capacity without variable speed blower	$1,223.36	$379.96
		Baseline	78 AFUE (1.242 HIR) Furnace assumed 90 kBtuh capacity without variable speed blower	$714.81	-
		Measure	High Efficiency Furnace 94 AFUE(1.06 HIR) assumed 90 kBtuh capacity with variable speed blower	$1,571.41	$856.59
		Baseline	78 AFUE (1.242 HIR) Furnace assumed 100 kBtuh capacity without variable speed blower	$757.67	-
		Measure	High Efficiency Furnace 96 AFUE(1.03 HIR) assumed 100 kBtuh capacity with variable speed blower	$1,668.55	$910.87

Table 3-12: Incremental Equipment Price Estimates for Residential HVAC, Water Heating, and Shell (continued)

Technology	Measure Source	Match Pair	Description	Modeled Price	IMC
Split-System HP (residential and commercial)	DEER Measures	Baseline	13 SEER(11.07 EER) / 8.1 HSPF(3.28 COP) A/C Heat pump assumed 36 kBtuh capacity	$1,784.62	-
		Measure	14 SEER(12.19 EER) / 8.6 HSPF(3.52 COP) A/C Heat Pump assumed 36 kBtuh capacity	$2,332.91	$548.29
		Measure	15 SEER(12.70 EER) / 8.8 HSPF(3.74 COP) A/C Heat Pump assumed 36 kBtuh capacity	$2,881.20	$1,096.58
		Measure	16 SEER (12.06 EER) / 8.4 HSPF (3.48 COP) A/C Heat Pump assumed 36 kBtuh capacity	$3,429.49	$1,644.87
		Baseline	Split HP SEER = 13.0 assumed 18 kBtuh capacity	$892.77	-
		Measure	Split HP SEER = 14.0 (< 55 kBTUh) - Combined SEER 13 and SEER 14.5 hp assumed 18 kBtuh capacity	$1,441.06	$548.29
		Baseline	Split HP SEER = 13.0 (< 55 kbtuh), EER = 11.07, HSPF = 7.7, COP = 3.28; no Econo; 1-spd Fan assumed 24 kBtuh capacity	$1,190.06	-
		Measure	Split HP SEER = 14.0 (< 55 kbtuh), EER = 12.00, HSPF = 8.50, COP = 3.74; no Econo; 1-spd Fan assumed 24 kBtuh capacity	$1,738.35	$548.29
		Measure	Split HP SEER = 15.0 (< 55 kBtuh), EER = 12.5, HSPF = 9.00, COP = 3.96; no Econo; 1-spd Fan assumed 24 kBtuh capacity	$2,286.64	$1,096.58
		Baseline	Split HP SEER = 13.0 assumed 60 kBtuh capacity	$2,973.74	-
		Measure	Split HP SEER = 14.0 (55-64 kBTUh) - Combined SEER 13 and SEER 14.5 hp assumed 60 kBtuh capacity	$3,522.03	$548.29
		Baseline	Split HP SEER = 13.0 (55-64 kbtuh), EER = 11.07, HSPF = 7.7, COP = 3.28; w/Econo; 2-spd Fan assumed 60 kBtuh capacity	$2,973.74	-
		Measure	Split HP SEER = 14.0 (55-64 kbtuh), EER = 12.00, HSPF = 8.50, COP = 3.74; w/Econo; 2-spd Fan assumed 60 kBtuh capacity	$3,522.03	$548.29
		Measure	Split HP SEER = 15.0 (55-64 kBTUh), EER = 12.5, HSPF = 9.00, COP = 3.96; w/Econo; 2-spd Fan assumed 60 kBtuh capacity	$4,070.32	$1,096.58

Table 3-12: Incremental Equipment Price Estimates for Residential HVAC, Water Heating, and Shell (continued)

Technology	Measure Source	Match Pair	Description	Modeled Price	IMC
Split-System DX (residential and commercial)	DEER Measures	Baseline	13 SEER (11.09 EER) Split System Air Conditioner assumed 36 kBtuh capacity	$1,268.55	-
		Measure	14 SEER(12.15 EER) Split-System Air Conditioner assumed 36 kBtuh capacity	$1,544.93	$276.38
		Measure	15 SEER(12.72 EER) Split-System Air Conditioner assumed 36 kBtuh capacity	$1,821.31	$552.76
		Measure	16 SEER (11.61 EER) Split System Air Conditioner assumed 36 kBtuh capacity	$2,097.69	$829.14
		Measure	17 SEER (12.28 EER) Split-System Air Conditioner assumed 36 kBtuh capacity	$2,374.07	$1,105.52
		Measure	18 SEER (13.37 EER) Split-System Air Conditioner assumed 36 kBtuh capacity	$2,650.45	$1,381.90
		Measure	19 SEER (13.82 EER) Split-System Air Conditioner assumed 36 kBtuh capacity	$2,926.83	$1,658.28
		Measure	20 SEER (14.43 EER) Split-System Air Conditioner assumed 36 kBtuh capacity	$3,203.21	$1,934.66
		Measure	21 SEER (15.03 EER) Split-System Air Conditioner assumed 36 kBtuh capacity	$3,479.59	$2,211.04
		Baseline	Split AC SEER = 13.0 (< 55 kBtuh), EER = 11.06, Clg EIR = 0.2557, Supply Fan W/cfm = 0.379; no Econo; 1-spd Fan assumed 24 kBtuh capacity	$937.34	-
		Measure	Split AC SEER = 14.0 (< 55 kBtuh), EER = 12.04, Clg EIR = 0.2456, Supply Fan W/cfm = 0.306; no Econo; 1-spd Fan assumed 24 kBtuh capacity	$1,213.72	$276.38
		Baseline	Split AC SEER = 13.0 (55-64 kBtuh), EER = 11.06, Clg EIR = 0.2557, Supply Fan W/cfm = 0.379; no Econo; 2-spd Fan assumed 60 kBtuh capacity	$1,930.98	-
		Measure	Split AC SEER = 14.0 (55-64 kBtuh), EER = 12.04, Clg EIR = 0.2456, Supply Fan W/cfm = 0.306; no Econo; 2-spd Fan assumed 60 kBtuh capacity	$2,207.36	$276.38
HVAC Fan Motors	Workpaper Measure	Baseline	0.5 HP Permanent Split Capacitor Motor	$261.74	-
		Measure	0.5 HP Brushless Fan Motor	$352.42	$90.68
Batt Insulation	DEER Measures	Baseline	Absence of insulation, or leaving the vintage-specific existing insulation as noted in measure definitions	-	-
		Measure	Ceiling R-0 to R-30 Insulation-Batts	$0.53	$0.53
		Measure	Ceiling R-0 to R-38 Insulation-Batts	$0.66	$0.66
		Measure	Ceiling add R-11 Batts on existing (vintage-specific)	$0.22	$0.22
		Measure	Ceiling add R-19 Batts on existing (vintage-specific)	$0.35	$0.35
		Measure	Ceiling add R-30 Batts on existing (vintage-specific)	$0.53	$0.53
		Measure	Floor R-0 to R-19 Insulation Batts	$0.35	$0.35
		Measure	Floor R-0 to R-30 Insulation Batts	$0.53	$0.53
		Measure	Floor R-19 to R-30 Insulation-Batts	$0.35	$0.35
		Measure	Wall 2x4 R-15 Insulation-Batts	$0.28	$0.28
		Measure	Wall 2x6 R-19 Insulation-Batts	$0.35	$0.35
		Measure	Wall 2x6 R-21 Insulation-Batts	$0.38	$0.38
		Measure	Wall 2x4 R-13 Batts + R-5 Rigid	$0.25	$0.25
		Measure	Wall 2x6 R-19 Batts + R-5 Rigid	$0.35	$0.35

Table 3-12: Incremental Equipment Price Estimates for Residential HVAC, Water Heating, and Shell (continued)

Technology	Measure Source	Match Pair	Description	Modeled Price	IMC
Small Storage Gas WH (<= 75,000 BtuH and EF rated)	DEER Measures	Baseline	Small Gas Storage Water Heater 30 Gal; EF = 0.61; Recov Eff = 0.76	$514.42	-
		Measure	High Efficiency Small Gas Storage Water Heater - 30 Gal , 0.62 EF	$712.56	$198.14
		Measure	High Efficiency Small Gas Storage Water Heater - 30 Gal , 0.65 EF	$793.03	$278.61
		Measure	High Efficiency Small Gas Storage Water Heater - 30 Gal , 0.70 EF	$927.15	$412.73
		Baseline	Small Gas Storage Water Heater 40 Gal; EF = 0.59; Recov Eff = 0.76	$565.05	-
		Measure	High Efficiency Small Gas Storage Water Heater - 40 Gal , 0.62 EF	$816.84	$251.79
		Measure	High Efficiency Small Gas Storage Water Heater - 40 Gal , 0.67 EF	$950.96	$385.91
		Measure	High Efficiency Small Gas Storage Water Heater - 40 Gal , 0.70 EF	$1,031.43	$466.38
		Baseline	Small Gas Storage Water Heater 50 Gal; EF = 0.57; Recov Eff = 0.76	$615.68	-
		Measure	High Efficiency Small Gas Storage Water Heater - 50 Gal , 0.62 EF	$921.12	$305.44
		Measure	High Efficiency Small Gas Storage Water Heater - 50 Gal , 0.67 EF	$1,055.23	$439.56
		Measure	High Efficiency Small Gas Storage Water Heater - 50 Gal , 0.70 EF	$1,135.71	$520.03
		Baseline	Small Gas Storage Water Heater 60 Gal; EF = 0.56; Recov Eff = 0.76	$693.13	-
		Measure	High Efficiency Small Gas Storage Water Heater - 60 Gal , 0.62 EF	$1,025.39	$332.26
		Measure	High Efficiency Small Gas Storage Water Heater - 60 Gal , 0.66 EF	$1,132.69	$439.56
		Measure	High Efficiency Small Gas Storage Water Heater - 60 Gal , 0.70 EF	$1,239.98	$546.85
		Baseline	Small Gas Storage Water Heater 75 Gal; EF = 0.53; Recov Eff = 0.76	$769.08	-
		Measure	High Efficiency Small Gas Storage Water Heater - 75 Gal , 0.62 EF	$1,181.81	$412.73
		Measure	High Efficiency Small Gas Storage Water Heater - 75 Gal , 0.66 EF	$1,289.11	$520.03
		Measure	High Efficiency Small Gas Storage Water Heater - 75 Gal , 0.70 EF	$1,396.40	$627.32

Table 3-12: Incremental Equipment Price Estimates for Residential HVAC, Water Heating, and Shell (continued)

Technology	Measure Source	Match Pair	Description	Modeled Price	IMC
Electric Storage WH	DEER Measures	Baseline	Small Electric Storage Water Heater 30 Gal; EF = 0.93; Recov Eff = 0.98	$361.48	$205.09
		Measure	High Efficiency Small Electric Storage Water Heater - 30 Gal, 0.95 EF	$566.57	
		Baseline	Small Electric Storage Water Heater 40 Gal; EF = 0.92; Recov Eff = 0.98	$420.93	$205.09
		Measure	High Efficiency Small Electric Storage Water Heater - 40 Gal, 0.94 EF	$626.01	
		Baseline	Small Electric Storage Water Heater 50 Gal; EF = 0.90; Recov Eff = 0.98	$377.83	$307.63
		Measure	High Efficiency Small Electric Storage Water Heater - 50 Gal, 0.93 EF	$685.46	
		Baseline	Small Electric Storage Water Heater 60 Gal; EF = 0.89; Recov Eff = 0.98	$437.27	$307.63
		Measure	High Efficiency Small Electric Storage Water Heater - 60 Gal, 0.92 EF	$744.90	
		Baseline	Small Electric Storage Water Heater 75 Gal; EF = 0.87; Recov Eff = 0.98	$475.17	$410.17
		Measure	High Efficiency Small Electric Storage Water Heater - 75 Gal, 0.91 EF	$885.34	
Tankless WH	DEER Measures	Baseline	Small Gas Storage Water Heater 40 Gal; EF = 0.59; Recov Eff = 0.76	$565.05	-
		Measure	High Efficiency Medium Gas Instantaneous Water heater , 0.82 TE, 120 mbtu/hr	$593.30	$28.26
		Measure	High Efficiency Medium Gas Instantaneous Water heater, 0.91 TE, 180 mbtu/hr	$1,166.83	$601.78
		Measure	High Efficiency Medium Gas Instantaneous Water heater, 0.93 TE, 150 mbtu/hr	$993.65	$428.61
		Baseline	Small Gas Storage Water Heater 75 Gal; EF = 0.53; Recov Eff = 0.76	$769.08	-
		Measure	High Efficiency Large Gas Instantaneous Water heater, 0.82 TE, 200 mbtu/hr	$1,148.30	$379.23
		Measure	High Efficiency Large Gas Instantaneous Water heater, 0.84 TE, 250 mbtu/hr	$1,530.13	$761.05
		Measure	High Efficiency Large Gas Instantaneous Water heater, 0.92 TE, 200 mbtu/hr	$1,323.05	$553.98
Heat Pump WH	Example Measures	Baseline	Small Electric Storage Water Heater 40 Gal; EF = 0.92; Recov Eff = 0.98	$420.93	-
		Measure	Heat pump water heater, 40 gallons, 4.0 kw, 2.0 EF, 240 volt	$1,761.23	$1,340.30
		Measure	Heat pump water heater, 50 gallons, 4.5 kw, 2.4 EF, 240 volt	$1,565.41	$1,187.58
		Measure	Heat pump water heater, 50 gallons, 5.5 kw, 2.45 EF, 230 volt	$1,295.82	$917.99
		Measure	Heat pump water heater, 60 gallons, 4.5 kw, 2.33 EF, 240 volt	$1,852.46	$1,415.19
		Measure	Heat pump water heater, 80 gallons, 2.2 kw, 2.51 EF, 240 volt	$2,706.37	$2,231.20
		Measure	Heat pump water heater, 80 gallons, 4.5 kw, 2.33 EF, 240 volt	$2,317.06	$1,841.89

3.4 Nonresidential Lighting

3.4.1 Data Development Process

For nonresidential lighting measures, the study team collected unit price data at the distributor level. For replacement linear fluorescent ballasts, bi-level fixtures, photocells, and occupancy sensors, the original price samples collected by the study team included a sufficient range of capacities, configurations, and efficiencies (where relevant) to enable robust price modeling. In these cases, the study team backfilled product characteristics using product-specific cut sheets.

For linear fluorescent lamps and fixtures and HID lamps and fixtures, the study team strategically added to the original price samples multiple times in order to ensure that those price samples adequately represented the full range of capacities and efficiency levels specified in DEER and the IOU workpapers and the various possible combinations within. In the specific case of linear fluorescent lamps, the study team used on-site survey data from WO29 to develop sample distribution targets for lamp length and brand to ensure that the linear lamp price sample was sufficiently representative of the California market. The study team then backfilled each price record with product characteristics using a combination of the USDOE's Compliance Certification Database and product-specific cut sheets.

Table 3-13 shows the final data sources used for the unit price estimates for nonresidential lighting measures. As the table shows, the study team used price lookups from online retailers and distributors to validate the predicted unit prices for these measures.[21]

[21] Including but not limited to Platt Electric Supply, Bulbs.com, Elightbulbs.com, Globalindustrial.com, and a host of smaller specialty distributors.

Table 3-13: Final Data Sources for Unit Price Estimates – Nonresidential Lighting

<table>
<tr><th>Technology</th><th>Primary Price Data Source</th><th>Product Characteristics Source</th><th>Roll-up Weight Source</th><th>Price Validation Source</th></tr>
<tr><td>HID Lamps</td><td rowspan="16">Distributor price lists</td><td rowspan="7">USDOE; product cut sheets</td><td rowspan="4">N/A</td><td rowspan="16">Online retailer price lookups</td></tr>
<tr><td>Linear Fluorescent T8 (48")</td></tr>
<tr><td>Linear Fluorescent T8 (24" & 36")</td></tr>
<tr><td>Linear Fluorescent T8 (96")</td></tr>
<tr><td>Linear Fluorescent T5 (all lengths)</td><td>WO29</td></tr>
<tr><td>Linear Fluorescent Ballasts (CEE/NEMA certified)</td><td rowspan="2">N/A</td></tr>
<tr><td>Linear Fluorescent Ballasts (non-CEE/NEMA certified)</td></tr>
<tr><td>General Service Linear Fluorescent Fixtures (recessed w/cover)</td><td rowspan="9">Product cut sheets</td><td rowspan="8">Price sample</td></tr>
<tr><td>General Service Linear Fluorescent Fixtures (recessed no cover)</td></tr>
<tr><td>General Service Linear Fluorescent Fixtures (surface mounted)</td></tr>
<tr><td>General Service Linear Fluorescent Fixtures (suspended)</td></tr>
<tr><td>High Bay Linear Fluorescent Fixtures</td></tr>
<tr><td>Bi-Level Linear Fluorescent Fixtures (garage/stairwell lighting)</td></tr>
<tr><td>HID Fixtures</td></tr>
<tr><td>Photocells (sensor only)</td></tr>
<tr><td>Occupancy Sensors</td><td>N/A</td></tr>
</table>

3.4.2 Market Assessment Findings

In developing the unit price samples for nonresidential lighting measures, the study team found that the relative availability (and diversity) of 8’ linear fluorescent lamps and fixtures to be significantly smaller than that for 4’ lamps and fixtures and even 2’ and 3’ lamps and fixtures. Indeed, the study team found comparatively wider availability of 4’ fixtures that featured modular, “tandem” designs that allow two 4’ fixtures (each using 4’ lamps) to be installed in series and wired to function as a single fixture.

When developing the price sample for replacement linear fluorescent ballasts, the study team found that the availability of magnetic ballasts to be extremely low and strictly limited to the replacement market for T12 systems. The study team also found the availability of bi-level linear fluorescent fixtures (for stairwell and garage lighting applications) to also be very limited (only 4 manufacturers total). In this case, however, the limited product availability appears to reflect the relative “newness” of this technology as a commercial offering rather than a legacy technology that is slowly being phased out.

In perhaps the most extreme case, the study team was only able to identify two manufacturers that currently produce PSMH fixtures with electronic ballasts. Indeed, despite multiple efforts to collect price data for those products, the study team could not collect enough price data to support robust estimates of incremental cost of these fixtures relative to PSMH fixtures with constant-wattage autotransformer (CWA) ballasts. However, the study team was able to collect a large sample of prices for PSMH fixtures with CWA ballasts, which served as one of the incremental cost baselines for T5 fixtures.

3.4.3 Modeling Process

For linear fluorescent lamps, the initial price datasets revealed extensive collinearity issues across multiple variables of interest, including watts, lamp length, and lumens. To address this, the study team decided to segment the analysis by lamp length. Within each length-specific model, the study team also specified a luminous efficacy variable (lumens per watt) rather than a variable for total light output (lumens). These adjustments yielded more intuitive results but with poor model fits due to large variations in distributor pricing for identical products. To improve overall model fit, the study team then solicited additional distributor price lists to increase the sample size for all lamp lengths and conducted multiple iterations of cross-checking and backfilling the product characteristics associated with each price record. In particular, after backfilling using characteristics from the USDOE's Compliance Certification Database, the study team also added data on low-mercury content and safety coatings using product-specific cut sheets. These additional characteristics and a larger sample frame (over 500 price observations in total) yielded good model fit with intuitive and statistically significant coefficients.

For linear fluorescent fixtures, the study team dealt with two primary modeling issues. First, it became immediately clear from the initial price sample that a significant portion of price variations are due to fixture type alone (e.g. recessed, suspended, surface-mounted) and that prices for higher-end fixtures are highly influenced by the aesthetic value of the luminaire. In order to address this dynamic, the study team decided to segment the analysis by fixture type and further specify fixture sub-types (e.g. troffer, parabolic, etc) as variables within each model. As with linear fluorescent lamps, segmenting the original dataset resulted in more intuitive results but poor model fit, so the study team solicited additional distributor prices to increase the sample size for all fixture types (and sub-types) and conducted multiple iterations of cross-checking and backfilling the product characteristics associated with each price record. The most significant challenge in that process was identifying the type of ballast (e.g. instant start, program start, etc) provided with each fixture which is not always clearly indicated on product cut sheets. In the end, the additional product characteristics and larger sample frame (over 600 price observations) yielded good model fit with intuitive and statistically significant results. For HID lamps and fixtures, the study team built upon the lessons learned above which resulted in fewer iterations with respect to sample development and model specifications.

Table 3-14: Hedonic Price Model Results for Nonresidential Lighting

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
HID Lamps	Watts	Continuous	25-1500	0.02	2.23	0.008	N/A	0.019	N observations
	Lumens per watt	Continuous	11-120	0.32	3.61	0.090	N/A	0.325	178
	Color Temp (K)	Continuous	3000-4300	-0.01	-2.79	0.004	N/A	-0.011	N unit sales
	CRI	Continuous	60-93	0.13	0.65	0.195	N/A	0.126	Unknown
	Start Type	Categorical	Probe	0.00	.	.	N/A	0.000	R2
			Pulse	1.89	0.53	3.533	N/A	1.887	0.530
			Both	35.28	3.20	11.043	N/A	35.282	Intercept
	Shape	Categorical	Elliptical	-3.05	-0.81	3.747	0.674	-0.128	141.240
			PAR	24.50	3.34	7.335	0.079		MAE
			Tubular	0.00	.	.	0.247		11.031
	Rating	Categorical	E	-106.28	-5.73	18.544	0.640	-104.737	Contr. Markup
			O	-103.61	-5.52	18.766	0.354		N/A
			S	0.00	.	.	0.006		
	High Output	Binary	Yes	13.97	2.11	6.612	0.112	1.569	
			No	0.00	.	.	0.888		
	Integrated Ballast	Binary	Yes	22.16	1.76	12.562	N/A	22.157	
			No	0.00	.	.	N/A	0.000	
Linear Fluorescent T8 (48")	Watts	Continuous	25-32	-0.38	6.37	0.060	N/A	-0.381	N observations
	CRI	Continuous	73-90	0.15	3.73	0.040	N/A	0.150	165
	Rated Life (hours)	Continuous	15000-40000	0.00	1.76	0.000	N/A	0.000	N unit sales
	Efficacy (lumens/watt)	Continuous	56-105	-0.05	1.88	0.030	N/A	-0.050	Unknown
	Manufacturer - Earthtronics	Binary	Yes	-2.10	0.55	3.780	0.073	-0.153	R2
			No	0.00	.	.	0.927		0.718
	Safety Coating	Binary	Yes	10.66	15.49	0.690	0.036	0.385	Intercept
			No	0.00	.	.	0.964		6.990
	Low Mercury	Binary	Yes	0.79	2.19	0.360	0.747	0.590	MAE
			No	0.00	.	.	0.253		1.120
									Contr. Markup
									0.25

Table 3-14: Hedonic Price Model Results for Nonresidential Lighting (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
Linear Fluorescent T8 (24" & 36")	Watts	Continuous	15-28	-0.12	2.32	0.050	N/A	-0.122	N observations
	CRI	Continuous	75-86	0.02	0.41	0.060	N/A	0.020	83
	Efficacy (lumens/watt)	Continuous	75-95	0.13	2.63	0.050	N/A	0.130	N unit sales
	Manufacturer - Earthtronics	Binary	Yes	-3.03	6.94	0.440	0.000	0.000	Unknown
			No	0.00	.	.	1.000		R2
	Extra Long Life	Binary	Yes	1.43	4.51	0.320	0.373	0.534	0.620
			No	0.00	.	.	0.627		Intercept
									-5.460
									MAE
									0.866
									Contr. Markup
									0.25
Linear Fluorescent T8 (96")	Watts	Continuous	51-86	0.59	4.55	0.130	N/A	0.590	N observations
	CRI	Continuous	75-86	-0.30	0.83	0.360	N/A	-0.300	71
	Rated Life (hours)	Continuous	20000-36000	0.00	0.79	0.000	N/A	0.000	N unit sales
	Efficacy (lumens/watt)	Continuous	92-107	2.36	4.57	0.520	N/A	2.360	Unknown
	Safety Coating	Binary	Yes	34.60	12.69	2.730	0.155	5.361	R2
			No	0.00	.	.	0.845		0.762
									Intercept
									-222.560
									MAE
									4.570
									Contr. Markup
									0.25

Table 3-14: Hedonic Price Model Results for Nonresidential Lighting (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
Linear Fluorescent T5 (all lengths)	Watts	Continuous	14-54	0.01	0.96	0.013	N/A	0.013	N observations
	CRI	Continuous	82-85	0.65	4.34	0.149	N/A	0.651	203
	Efficacy (lumens/watt)	Continuous	73-138	0.07	3.58	0.019	N/A	0.067	N unit sales
	Low Mercury	Binary	Yes	3.60	7.42	0.485	0.542	1.951	Unknown
			No	0.00	.	.	0.458		R2
	Safety Coating	Binary	Yes	19.12	11.75	1.630	0.010	0.188	0.725
			No	0.00	.	.	0.990		Intercept
	Extra Long Life	Binary	Yes	1.46	2.47	0.593	0.118	0.173	-54.090
			No	0.00	.	.	0.882		MAE
	Manufacturer Earthtronics	Binary	Yes	-6.21	3.77	1.650	0.010	-0.061	1.570
			No	0.00	.	.	0.990		Contr. Markup
	Manufacturer - GE	Binary	Yes	-2.79	4.23	0.661	0.130	-0.363	0.25
			No	0.00	.	.	0.870		
	Manufacturer - Satco	Binary	Yes	-2.09	4.13	0.507	0.020	-0.042	
			No	0.00	.	.	0.980		
	Manufacturer - Sylvania	Binary	Yes	-1.65	3.56	0.465	0.210	-0.347	
			No	0.00	.	.	0.790		
Linear Fluorescent Ballasts (CEE/NEMA certified)	Ballast Input Watts	Continuous	19 - 116	0.16	1.90	0.085	N/A	N/A	N observations
	Ballast Factor	Continuous	.74 - 1.18	-11.27	0.54	21.040	N/A	N/A	31
	Dimmable	Binary	Yes	31.59	4.17	7.570	0.306	9.653	N unit sales
			No	0.00	.	.	0.694		Unknown
	Programmed Start	Binary	Yes	17.19	7.12	2.410	0.389	6.685	R2
			No	0.00	.	.	0.611		0.848
									Intercept
									21.920
									MAE
									7.920
									Contr. Markup
									0.00

Table 3-14: Hedonic Price Model Results for Nonresidential Lighting (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	**Type**	**Values**	**Coefficient**	**t-stat**	**Standard Error**	**Roll-up Wts**	**Wtd Coefficient**	
Linear Fluorescent Ballasts (non-CEE/NEMA certified)	Ballast Input Watts	Continuous	9 - 604	0.40	9.85	0.040	N/A	0.400	N observations
	Ballast Factor	Continuous	.60 - 1.2	10.56	0.31	34.520	N/A	N/A	63
	Dimmable	Binary	Yes	30.78	2.14	14.390	0.052	1.603	N unit sales
			No	0.00	.	.	0.948		Unknown
	Electronic Instant Start	Binary	Yes	-37.61	-4.66	8.060	0.177	-6.660	R2
			No	0.00	.	.	0.823		0.823
	Magnetic Rapid Start	Binary	Yes	40.89	3.47	11.780	0.194	7.928	Intercept
			No	0.00	.	.	0.786		14.690
									MAE
									20.730
									Contr. Markup
									0.00
Photocells (sensor only)	Foot-candle Range	Continuous	0-10000	0.00	-0.74	0.003	N/A	-0.002	N observations
	Outdoor Use	Binary	Yes	0.18	0.01	12.240	0.300	0.054	30
			No	0.00			0.700		N unit sales
	Mounting Type	Categorical	Vertical	10.59	0.79	13.442	0.400	4.908	Unknown
			Horizontal	1.68	0.12	14.337	0.400		R2
			Other	0.00	.	.	0.200		0.743
	Brand	Categorical	Cooper	22.37	1.60	13.977	0.733	7.269	Intercept
			Intermatic	-68.55	-3.37	20.339	0.133		88.049
			Other	0.00	.	.	0.133		MAE
									13.228
									Contr. Markup
									0.20

Table 3-14: Hedonic Price Model Results for Nonresidential Lighting (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
Occupancy Sensors	Coverage (ft2)	Continuous	90 - 2,152	0.00	0.36	0.006	N/A	0.006	N observations
	Battery Powered	Binary	Yes	-60.55	3.35	18.070	0.050	-3.028	40
			No	0.00	.	.	0.950		N unit sales
	Solar Powered	Binary	Yes	49.27	2.21	22.330	0.025	1.232	Unknown
			No	0.00	.	.	0.975		R2
	Outdoor	Binary	Yes	178.88	14.08	12.710	0.075	13.416	0.927
			No	0.00	.	.	0.925		Intercept
	Two Loads	Binary	Yes	101.15	5.91	17.130	0.050	5.058	117.420
			No	0.00	.	.	0.950		MAE
	Ultrasonic	Binary	Yes	42.36	5.14	8.240	0.375	15.885	12.310
			No	0.00	.	.	0.625		Contr. Markup
	12 volt	Binary	Yes	-49.53	2.22	22.330	0.025	-1.238	0.00
			No	0.00	.	.	0.975		
	18 volt	Binary	Yes	48.54	4.10	11.830	0.075	3.641	
			No	0.00	.	.	0.925		
	24 volt	Binary	Yes	-49.33	4.15	11.880	0.500	-24.665	
			No	0.00	.	.	0.500		
	120 volt	Binary	Yes	-34.27	3.00	11.420	0.300	-10.281	
			No	0.00	.	.	0.700		
	277 volt	Binary	Yes	-29.37	2.56	11.460	0.275	-8.077	
			No	0.00	.	.	0.725		

Table 3-14: Hedonic Price Model Results for Nonresidential Lighting (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
General Service Linear Fluorescent Fixtures (recessed w/cover)	Fixture length (inches)	Continuous	24-96	1.62	4.70	0.345	N/A	1.620	N observations
	Max Ballast Input Watts	Continuous	17-216	-0.17	1.21	0.141	N/A	-0.171	139
	Luminaire type - direct/indirect	Binary	Yes	33.17	2.37	13.992	N/A	33.168	N unit sales
			No	0.00	.	.	N/A	0.000	Unknown
	Luminaire type - trough	Binary	Yes	117.70	6.96	16.911	N/A	117.697	R2
			No	0.00	.	.	N/A	0.000	0.808
	Lamp type	Categorical	T5	38.32	3.71	10.325	N/A	38.317	Intercept
			T8	0.00	.	.	N/A	0.000	25.315
	Dimmable ballast	Binary	Yes	123.25	8.64	14.263	N/A	123.247	MAE
			No	0.00	.	.	N/A	0.000	29.150
	Manufacturer - Lamar	Binary	Yes	36.53	3.65	10.010	0.252	9.198	Contr. Markup
			No	0.00	.	.	0.748		0.25
	Manufacturer - Litolier	Binary	Yes	55.07	3.92	14.052	0.324	17.828	
			No	0.00	.	.	0.676		
	Manufacturer - Mercury	Binary	Yes	52.15	3.88	13.449	0.108	5.627	
			No	0.00	.	.	0.892		
General Service Linear Fluorescent Fixtures (recessed no cover)	Max Ballast Input Watts	Continuous	21-216	0.37	2.68	0.139	N/A	0.374	N observations
	Luminaire type - parabolic troffer	Binary	Yes	-81.23	8.60	9.450	N/A	-81.233	176
			No	0.00	.	.	N/A	0.000	N unit sales
	Luminaire type - troffer	Binary	Yes	-37.99	1.91	19.930	N/A	-37.993	Unknown
			No	0.00	.	.	N/A	0.000	R2
	Ballast start type	Categorical	Program rapid start	62.22	4.11	15.150	N/A	62.217	0.634
			Instant start	0.00	.	.	N/A	0.000	Intercept
	Dimmable ballast	Binary	Yes	120.99	7.33	16.510	N/A	120.989	160.300
			No	0.00	.	.	N/A	0.000	MAE
	Louvered cover	Binary	Yes	108.50	2.83	38.400	0.017	1.849	31.660
			No	0.00	.	.	0.983		Contr. Markup
	Size 96 inches	Binary	Yes	151.69	2.39	63.390	N/A	151.693	0.25
			No	0.00	.	.	N/A	0.000	
	Manufacturer - Lamar	Binary	Yes	20.71	2.18	9.480	0.261	5.413	
			No	0.00	.	.	0.739		
	Manufacturer - Litolier	Continuous	Yes	57.52	5.02	11.450	0.193	11.111	
			No	0.00	.	.	0.807		

Table 3-14: Hedonic Price Model Results for Nonresidential Lighting (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
General Service Linear Fluorescent Fixtures (surface mounted)	Max Ballast Input Watts	Continuous	17-236	0.162	2.58	0.06	N/A	0.162	N observations
	Fixture length (inches)	Continuous	24-96	0.558	0.14	3.97	N/A	0.558	124
	Luminaire type - direct/indirect	Binary	Yes	219.56	14.89	14.75	N/A	219.560	N unit sales
			No	0	.	.	N/A	0.000	Unknown
	Luminaire type - parabolic troffer	Binary	Yes	101.06	14.29	7.07	N/A	101.060	R2
			No	0	.	.	N/A	0.000	0.884
	Luminaire type - troffer	Binary	Yes	60.46	14.49	4.17	N/A	60.460	Intercept
			No	0	.	.	N/A	0.000	19.720
	Ballast start type	Categorical	Program rapid start	54.49	10.90	5.00	N/A	54.490	MAE
			Instant start	0	.	.	N/A	0.000	19.150
	Manufacturer - Mercury	Binary	Yes	34.45	15.47	2.23	0.081	2.778	Contr. Markup
			No	0	.	.	0.919		0.25
	Manufacturer - Metalux	Binary	Yes	95.43	4.97	19.21	0.040	3.848	
			No	0	.	.	0.960		
	Manufacturer - Simkar	Binary	Yes	30.11	1.86	16.21	0.048	1.457	
			No	0	.	.	0.952		
General Service Linear Fluorescent Fixtures (suspended)	Max Ballast Input Watts	Continuous	26-648	0.525	9.81	0.05	N/A	0.525	N observations
	Fixture length (inches)	Continuous	24-96	1.786	4.97	0.36	N/A	1.786	132
	Luminaire type - direct pendant	Binary	Yes	225.48	6.96	32.40	N/A	225.480	N unit sales
			No	0	.	.	N/A	0.000	Unknown
	Luminaire type - direct/indirect pendant	Binary	Yes	207.52	19.87	10.44	N/A	207.520	R2
			No	0	.	.	N/A	0.000	0.751
	Instant start ballast	Binary	Yes	-37.1	2.51	14.80	N/A	-37.100	Intercept
			No	0	.	.	N/A	0.000	4.900
	Program rapid start ballast	Binary	Yes	86.08	2.41	35.69	N/A	86.080	MAE
			No	0	.	.	N/A	0.000	41.310
	Dimmable ballast	Binary	Yes	66.69	32.12	2.08	N/A	66.690	Contr. Markup
			No	0	.	.	N/A	0.000	0.25
	Parabolic louvers	Binary	Yes	60.69	2.95	20.60	0.136	8.276	
			No	0	.	.	0.864		
	Wire guard	Binary	Yes	102.38	3.37	30.36	0.038	3.878	
			No	0	.	.	0.962		
	Manufacturer - Alera	Binary	Yes	-57.96	2.21	26.25	0.182	-10.538	
			No	0	.	.	0.818		
	Manufacturer - Lamar	Binary	Yes	-48.9	2.65	18.49	0.227	-11.114	
			No	0	.	.	0.773		
	Manufacturer - Litolier	Binary	Yes	-66.21	25.73	2.57	0.098	-6.521	
			No	0	.	.	0.902		
	Manufacturer - Mercury	Binary	Yes	-56.92	28.98	1.96	0.091	-5.175	
			No	0	.	.	0.909		

Table 3-14: Hedonic Price Model Results for Nonresidential Lighting (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
High Bay Linear Fluorescent Fixtures	Fixture length (inches)	Continuous	24-96	3.277	4.82	0.68	N/A	3.277	N observations
	Number of lamps	Continuous	2 - 10	16.608	4.28	3.88	N/A	16.608	52
	Lamp watts	Continuous	24-54	-1.358	-1.97	0.69	N/A	-1.358	N unit sales
	Lens	Binary	Yes	46.456	2.13	21.81	N/A	46.456	Unknown
			No	0	.	.	N/A	0.000	R2
	Occupancy sensor	Binary	Yes	100.635	2.07	48.54	N/A	100.635	0.658
			No	0	.	.	N/A	0.000	Intercept
	Program rapid start ballast	Binary	Yes	-1.925	0.10	19.73	N/A	-1.925	14.200
			No	0	.	.	N/A	0.000	MAE
	Manufacturer - Mercury	Binary	Yes	67.489	33.87	1.99	0.077	5.191	34.890
			No	0	.	.	0.923		Contr. Markup
									0.25
Bi-Level Linear Fluorescent Fixtures (garage/stairwell lighting)	Max Ballast Input Watts	Continuous	17-64 (full output)	-0.14649	-0.63	0.23	N/A	-0.146	N observations
	Emergency backup power	Binary	Yes	117.1066	16.60	7.05	N/A	117.107	23
			No	0	.	.	N/A	0.000	N unit sales
	Dimmable ballast	Binary	Yes	45.67074	5.83	7.83	N/A	45.671	Unknown
			No	0	.	.	N/A	0.000	R2
	Brand	Categorical	Atlite	69.18141	4.65	14.87	0.043	15.323	0.980
			Lamar	0	.	.	0.652		Intercept
			Lutron	10.67589	1.29	8.29	0.174		222.088
			SureLites	80.18141	7.53	10.65	0.130		MAE
									8.765
									Contr. Markup
									0.20
HID Fixtures	Size	Continuous	14-22	7.10	4.95	1.43	N/A	7.100	N observations
	Watts	Continuous	150-1000	0.06	2.54	0.02	N/A	0.060	58
	Manufacturer - Warehouse	Binary	Yes	-65.13	7.81	8.34	0.534	-34.811	N unit sales
			No	0	.	.	0.466		Unknown
	Manufacturer - Howard	Binary	Yes	-65.42	4.12	15.88	0.069	-4.512	R2
			No	0	.	.	0.931		0.681
	Acrylic Lens	Binary	Yes	16.66	2.01	8.28	N/A	16.66	Intercept
			No	0	.	.	N/A	0	86.000
	480V only	Binary	Yes	54.86	3.84	14.29	N/A	54.86	MAE
			No	0	.	.	N/A	0	21.03
									Contr. Markup
									0.20

3.4.4 Roll-up Weights

The price models developed for nonresidential lighting measures included statistically significant relationships between brand and price for multiple types of linear fluorescent lamps and linear fluorescent fixtures. In order to aggregate these brand effects into market-averages, the study team developed roll-up weights using on-site survey data of recent nonresidential lighting program participants (from WO29) wherever possible.

Specifically, the final price models for T5 lamps included statistically significant brand effects for multiple brands. In this case, brand shares for T5 lamps from the WO29 survey data were applied as roll-up weights. In the final T8 lamp models, price effects were observed for one brand (Earthtronics – the least expensive products in the sample), but these price effects were only statistically significant for 2’ and 3’ lamps. Unfortunately, the WO29 survey data did not include any observations for Earthtronics lamps, so the study team used the share of Earthtronics products in the sample as proxy for market share.

For linear fluorescent fixtures, the final price models included significant brand effects for all fixture types. It should be noted, however, that in this case, the estimated effect of brand on fixture price likely also captures price effects related to luminaire design aesthetics. Unfortunately, the WO29 survey data did not include brand information on fixtures, which is understandable given that brand is not easily observed on installed linear fixtures.[22] In these cases, the study team used the brand shares in the price sample (by fixture type) as proxies for market shares.

3.4.5 Model Results and Findings

Table 3-15 presents the study team’s estimates of incremental equipment prices for nonresidential lighting measures.[23]

As the table shows, the study team found statistically significant but relatively low incremental costs for 4’ T8 lamps (28W compared to 32W baseline). These incremental cost estimates ($1.22 to $2.02 per lamp, depending on rated life) represent a slight decrease from previous DEER estimates. For 4’ T5 lamps (replacing 4’ T8 lamps), the study team again found incremental costs that are slightly lower than current DEER estimates ($7.36 per lamp). The

[22] Identifying the brand of installed fixtures would likely require disassembling the fixtures or going behind ceiling panels, both of which are highly invasive and normally outside the scope of on-site surveys commissioned for EM&V studies.

[23] The complete set of incremental cost estimates based on the measure definitions from READI v.1.0.4 “Draft Combined DEER 2011 and DEER 2014 plus IOU Ex Ante for the 2013-14 Cycle” is provided in Appendix F.

study team also found statistically significant incremental costs for 2', 3', and 8' T8 lamps which validated well compared to a small sample of online price lookups.[24]

Because fixture type is not defined in current DEER and IOU workpaper estimates, the predicted prices and incremental costs for linear fluorescent fixtures produced by the study team are not directly comparable. Furthermore, the incremental costs shown in Table 3-15 do not include the cost of the lamps, only the luminaire and the ballast. Since the total fixture wattage is dependent on the specific lamps installed with the luminaire, the incremental costs shown in Table 3-15 only reflect the price impact of specifying lower wattage ballasts and/or alternative ballast types (e.g. program start or dimmable) – which in most cases is a statistically significant but small price effect. Where incremental fixture costs are higher (again without accounting for the cost of the lamps) are the cases where T5 fixtures replace baseline T8 fixtures. Note that full installed fixture costs (luminaire + ballast + lamps + installation costs) for all in-scope fixtures are provided in Appendix F.

[24] Incremental costs estimates for these specific lamp lengths were not included in previous DEER.

Table 3-15: Incremental Equipment Price Estimates for Nonresidential Lighting

Technology	Measure Source	Match Pair	Description	Modeled Price	IMC
Linear Fluorescent T8 (48")	Example Measures	Baseline	T8, 48 inch, 32 watt, 2850 lumens, 24000 hr rated life, 89 lumens per watt, CRI 85	$6.10	-
		Measure	T8, 48 inch, 28 watt, 2800 lumens, 24000 hr rated life, 100 lumens per watt, CRI 85	$7.32	$1.22
		Measure	T8, 48 inch, 28 watt, 2800 lumens, 40000 hr rated life, 100 lumens per watt, CRI 85	$8.12	$2.02
Linear Fluorescent T8 (24" & 36")	Example Measures	Baseline	T8, 36 inch, 25 watt, 2175 lumens, 87 lumens per watt, CRI 85	$5.63	-
		Measure	T8, 36 inch, 21 watt, 2100 lumens, 100 lumens per watt, CRI 85	$8.35	$2.72
		Baseline	T8, 24 inch, 17 watt, 1375 lumens, 80 lumens per watt, CRI 85	$5.71	-
		Measure	T8, 24 inch, 15 watt, 1375 lumens, 90 lumens per watt, CRI 85	$7.64	$1.93
Linear Fluorescent T8 (96")	Example Measures	Baseline	T8, 96 inch, 59 watt, 57000 lumens, 36000 hr rated life, 95 lumens per watt, CRI 85	$11.39	-
		Measure	T8, 96 inch, 55 watt, 57000 lumens, 36000 hr rated life, 103 lumens per watt, CRI 85	$32.04	$20.65
Linear Fluorescent T5 (all lengths)	Example Measures	Baseline	T8, 48 inch, 32 watt, 2850 lumens, 24000 hr rated life, 89 lumens per watt, CRI 85	$6.10	-
		Measure	T5, 48 inch, 28 watts, 2895 lumens, 24000 hr rated life, 103 lumens per watt, CRI 85	$13.46	$7.36
Linear Fluorescent Ballasts (CEE/NEMA certified)	Workpaper Measures	Baseline	Electronic ballast (non-dimmable) assumed cee/nema certified, programmed start, 73 input watts, 1.18 BF	$20.37	-
		Measure	Electronic ballast (dimmable) assumed cee/nema certified, programmed start ,76 input watts, 1.17 BF	$69.75	$49.38
		Baseline	Electronic ballast (non-dimmable) assumed cee/nema certified, instant start, 93 input watts, 0.89 BF	$26.86	-
		Measure	Electronic ballast (dimmable) assumed cee/nema certified, programmed start, 96 input watts, 0.97 BF	$75.22	$48.36
Linear Fluorescent Ballasts (non-CEE/NEMA certified)	Workpaper Measures	Baseline	Electronic ballast (non-dimmable) assumed non-cee/nema certified, instant start, 65 input watts, 1.03 BF	$13.96	-
		Measure	Electronic ballast (dimmable) assumed non-cee/nema certified, programmed start, 62 input watts, 0.99 BF	$80.72	$66.77
		Baseline	Electronic ballast (non-dimmable) assumed non-cee/nema certified, programmed start, 98 input watts, 0.95 BF	$63.92	-
		Measure	Electronic ballast (dimmable) assumed non-cee/nema certified, programmed start, 125 input watts, 1.0 BF	$106.03	$42.11
General Service Linear Fluorescent Fixtures (recessed w/cover)	Example Measures	Base	T8, 48 inch, 2-lamp, 32 watt, instant start ballast, recessed troffer w/cover (lamps not included)	$92.13	-
		Measure	T8, 48 inch, 2-lamp, 30 watt, instant start ballast, recessed troffer w/cover (lamps not included)	$92.82	$0.68
		Measure	T8, 48 inch, 2-lamp, 28 watt, instant start ballast, recessed troffer w/cover (lamps not included)	$93.50	$1.37
		Base	T8, 48 inch, 4-lamp, 32 watt, instant start ballast, recessed troffer w/cover (lamps not included)	$81.19	-
		Measure	T5, 48 inch, 3-lamp, 28 watt, program start ballast, recessed troffer w/cover (lamps not included)	$88.71	$7.52

Table 3-15: Incremental Equipment Price Estimates for Nonresidential Lighting (continued)

Technology	Measure Source	Match Pair	Description	Modeled Price	IMC
General Service Linear Fluorescent Fixtures (recessed no cover)	Example Measures	Base	T8, 48 inch, 2-lamp, 32 watt, instant start ballast, recessed troffer no cover (lamps not included)	$184.24	-
		Measure	T8, 48 inch, 2-lamp, 30 watt, instant start ballast, recessed troffer no cover (lamps not included)	$182.74	($1.50)
		Measure	T8, 48 inch, 2-lamp, 28 watt, instant start ballast, recessed troffer no cover (lamps not included)	$181.99	($2.24)
		Base	T8, 48 inch, 4-lamp, 32 watt, instant start ballast, recessed troffer no cover (lamps not included)	$208.17	-
		Measure	T5, 48 inch, 3-lamp, 28 watt, program start ballast, recessed troffer no cover (lamps not included)	$191.72	($16.46)
General Service Linear Fluorescent Fixtures (surface mounted)	Example Measures	Base	T8, 48 inch, 2-lamp, 32 watt, instant start ballast, surface mounted strip (lamps not included)	$56.87	-
		Measure	T8, 48 inch, 2-lamp, 30 watt, instant start ballast, surface mounted strip (lamps not included)	$56.22	($0.65)
		Measure	T8, 48 inch, 2-lamp, 28 watt, instant start ballast, surface mounted strip (lamps not included)	$55.90	($0.97)
		Base	T8, 48 inch, 4-lamp, 32 watt, instant start ballast, surface mounted strip (lamps not included)	$67.24	-
		Measure	T5, 48 inch, 3-lamp, 28 watt, program start ballast, surface mounted strip (lamps not included)	$60.11	($7.13)
General Service Linear Fluorescent Fixtures (suspended)	Example Measures	Base	T8, 48 inch, 2-lamp, 32 watt, instant start ballast, suspended low bay (lamps not included)	$87.13	-
		Measure	T8, 48 inch, 2-lamp, 30 watt, instant start ballast, suspended low bay (lamps not included)	$85.03	($2.10)
		Measure	T8, 48 inch, 2-lamp, 28 watt, instant start ballast, suspended low bay (lamps not included)	$83.98	($3.15)
		Base	T8, 48 inch, 4-lamp, 32 watt, instant start ballast, suspended low bay (lamps not included)	$120.73	-
		Measure	T5, 48 inch, 3-lamp, 28 watt, program start ballast, suspended low bay (lamps not included)	$134.73	$14.00
High Bay Linear Fluorescent Fixtures	Example Measures	Base	PSMH, 1-lamp, 456 watt, CWA ballast (lamp not included)	$216.04	-
		Measure	T5, 48 inch, 6-lamp, 54 watt, program start ballast (lamps not included)	$197.81	($18.23)
		Base	T8, 96 inch, 4-lamp, 59 watt, instant start ballast (lamps not included)	$263.16	-
		Measure	T5, 48 inch, 6-lamp, 54 watt, program start ballast (lamps not included)	$197.81	($65.34)
Bi-Level Linear Fluorescent Fixtures (garage/stairwell lighting)	Workpaper Measure	Baseline	T8, 48 inch, 2-lamp, 32 watt, instant start ballast, surface mounted wrap (lamps not included)	$56.87	-
		Measure	Two lamp 4 foot 64 watt linear fluorescent fixture with integrated occupancy sensor - no dimming or emergency ballast	$273.64	$216.77
	Example Measures	Measure	Two lamp 4 foot 64 watt linear fluorescent fixture with integrated occupancy sensor - no dimming w/ emergency ballast	$414.17	$357.30
		Measure	Two lamp 4 foot 64 watt linear fluorescent fixture with integrated occupancy sensor - w/ dimming w/ emergency ballast	$468.97	$412.10

Table 3-15: Incremental Equipment Price Estimates for Nonresidential Lighting (continued)

Technology	Measure Source	Match Pair	Description	Modeled Price	IMC
Photocells (sensor only)	Workpaper Measure	Baseline	No Photocell	-	-
		Measure	Add photocell to existing timeclock control assumed foot-candle range of 5000 foot-candles	$108.57	$108.57
Occupancy Sensors	DEER Measures	Baseline	Absence of occupancy sensor, manually controlled switch	$0.00	-
		Measure	Occupancy sensor (300 sqft) assumed ceiling mount, passive infrared, indoor, 24v	$87.36	$87.36
		Measure	Occupancy sensor (1000 sqft) assumed ceiling mount, passive infrared & ultrasonic, indoor, 120v	$164.39	$164.39
	Example Measures	Measure	Occupancy sensor (2000 sqft) ceiling mount, passive infrared, indoor, 24v	$323.71	$323.71
		Measure	Occupancy sensor (2000 sqft) wall mount, passive infrared & ultrasonic, indoor, 120v	$164.39	$164.39

3.5 Nonresidential HVAC, Water Heating, and Shell

3.5.1 Data Development Process

For nonresidential HVAC, water heating, and shell measures, the study team collected unit price data at the distributor level.

For fan variable-frequency drives (VFDs), and demand-controlled ventilation (DCV), the original price samples collected by the study team included a sufficient range of capacities, configurations, efficiencies (where relevant), and other product characteristics to enable robust price modeling and very little additional data development was required.

For all other nonresidential HVAC, water heating, and shell measures, the distributor price samples included only basic capacity and efficiency information (in addition to brand, model number, and unit price). For these technologies, the study team backfilled key product characteristics using a combination of the CEC Appliance Database and product-specific cut sheets. In the case of indirect evaporative coolers, the study team also reached out directly to manufacturers in order to determine and/or confirm key product characteristics – in particular, whether units included an integrated furnace. Once the study team had firmly established which units (and their associated prices) included integrated furnaces, the team then requested and received additional information from distributors that had the furnace costs explicitly excluded.

For several nonresidential HVAC technologies, the study team strategically added to the original price sample multiple times in order to ensure that those price samples adequately represented the full range of capacities and efficiency levels specified in DEER and the IOU workpapers and the various possible combinations within. These cases included service hot water (SHW) boilers (condensing and non-condensing), steam boilers, packaged HPs, and water-side economizers.

One particular data development challenge encountered by the study team was defining efficiency metrics for boilers. For this technology, Title 20 specifies different efficiency ratings (AFUE, thermal efficiency, combustion efficiency) depending on capacity and boiler type. However, the distributor price samples (and associated product data) and the information available in product-specific cut sheets did not always provide efficiency ratings in the same metric as specified by code or were unclear as to which efficiency metric applied. In order to ensure an internally-consistent analysis of the efficiency/price relationship for boilers, the study team used thermal efficiency (max rated output energy/rated input energy) as the efficiency variable for all boiler types other than small non-condensing SHW boilers (<300 MBH), for which consistent data was available in all product-specific cut sheets. For small non-condensing SHW boilers, the study team used AFUE as the efficiency metric, which was available for all models in the price sample from the CEC Appliance Database.

In order to validate predicted prices, the study team used a variety of primary and secondary data sources, depending on the technology. For fan VFDs, and large storage gas water heaters, the study team was able to validate predicted prices against a small sample of online retailer price lookups. However, all other nonresidential HVAC, water heating, and shell technologies are either large capital equipment and/or specialty equipment for which prices are seldom advertised online. For these technologies, the study team used a variety of secondary sources to benchmark predicted prices, including artificial project bids, previous DEER estimates, IOU workpaper estimates, and RSMeans. Table 3-16 shows the final data sources used to validate the predicted prices for nonresidential HVAC, water heating, and shell measures.

Table 3-16: Final Data Sources for Unit Price Estimates – Nonresidential HVAC, Water Heating, and Shell

Technology	Primary Price Data Source	Product Characteristics Source	Roll-up Weight Source	Price Validation Source
Fan VFDs (>10hp)	Distributor price lists	Distributors	N/A	Online retailer price lookups
Fan VFDs (<= 10hp)				
Demand Control Ventilation			Price sample	
Direct Evaporative Coolers (non-residential)		Distributors, CEC		DEER, IOU workpapers, RSMeans
Indirect Evaporative Coolers		Product cut sheets		
Small Packaged DX (<= 5 tons)		Distributors, CEC	CSS/CMST	
Large Packaged DX (> 5 tons)			N/A	DEER, IOU workpapers, artificial project bids, RSMeans
Air-Cooled Chillers		Distributors, product cut sheets	CEUS	
Water-Cooled Chillers (excluding centrifugal VSD)				
Water-Cooled Centrifugal VSD Chillers (>= 300 tons)				
Small Packaged HP (< 65,000 Btuh)		Distributors, CEC	CSS/CMST	DEER
Large Packaged HP (65,000 - 240,000 Btuh)			N/A	DEER, artificial project bids
Steam Boilers (non-process)		Distributors, product cut sheets	CEUS	DEER, artificial project bids, RSMeans
Waterside Economizers			Price sample	DEER, artificial project bids
Large Storage Gas WH (> 75,000 BtuH and TE rated)		Distributors, CEC	CLASS	Online retailer price lookups
SHW Boilers (< 300 kBtuh, non-condensing)		Distributors, product cut sheets	CEUS	DEER, IOU workpapers
SHW Boilers (> 300 kBtuh, non-condensing)				
SHW Boilers (condensing)				RSMeans
Thermal Curtain		Distributors, product cut sheet	N/A	Artificial project bids
Reflective Film				

3.5.2 Market Assessment Findings

In developing the unit price samples for nonresidential HVAC, water heating, and shell measures, the study team found that several specific technologies (or capacity ranges) had limited or no availability in the California market. Specifically, the study team found the following:

- HVAC contractors and engineers indicated that reciprocating chillers (currently a DEER measure) are no longer used for HVAC applications (retrofit or new). Reciprocating chillers are still available in the market but are now produced and designed strictly for industrial refrigeration applications.
- Regional air quality regulations in California (NO_x emissions) now severely restrict the use of atmospheric boilers in retrofit and new construction applications, making forced draft boilers the effective baseline for boiler projects.[25]
- Packaged HPs are no longer available in capacities greater than 20 tons. The study team confirmed with several manufacturers that such capacities are no longer produced.
- IOU workpapers indicate there are no water-cooled, centrifugal VSD chillers less than 150 tons in the market, which was confirmed by the study team. Additionally, the study team's subcontractors found very few (4) units less than 300 tons. Given the very small resulting sample size, a regression model could only be developed for centrifugal VSD chillers greater than or equal to 300 tons.

3.5.3 Modeling Process

The most challenging modeling issue encountered for nonresidential HVAC, water heating, and shell measures was for boilers and chillers. For each of these technologies, there are a significant number of distinct sub-technologies or types, e.g. compressor types for chillers. Ideally, the relationships between price, capacity, and efficiency should be analyzed *within* each of these specific technology types. However, the final price samples assembled by the study team only supported segmenting the analysis by air-cooled vs. water-cooled chillers and condensing vs. non-condensing boilers.

Given these segmentations, both efficiency and compressor type were therefore modeled as independent variables in the chiller models. The study team attempted to interact the efficiency and capacity variables in order to differentiate the price impacts of efficiency across size ranges (which would also act as a proxy for compressor type). However, these specifications produced counterintuitive results. The study team also attempted to estimate incremental costs using a matched pair analysis, but the number of strict matched pairs available from the same distributors was severely limited.

For direct evaporative coolers, the study team attempted to include both cubic feet per minute (CFM) and rated energy input (W) in the price model, but these variables were highly collinear. Similarly, there was an alternative efficiency metric (evaporative cooling efficiency ratio) available for all price records, but this variable was highly collinear with media saturation effectiveness which is the efficiency criteria specified in the IOU workpapers. In order to

25 See https://www.aceee.org/files/proceedings/2009/data/papers/6_92.pdf

maintain consistency with measure definitions in DEER and the IOU workpapers, the study team used CFM and media saturation effectiveness in the final model specifications for direct evaporative coolers.

For indirect evaporative coolers, the study team attempted to include horsepower (HP) and number of filters in the model, but these variables were highly collinear with CFM. Additionally, media saturation effectiveness was highly collinear with brand. In order to maintain consistency with the DEER measure definition, the study team attempted to include media saturation effectiveness and exclude brand from the model, but this specification produced counterintuitive results due to large variation in capacity and low variation in media saturation effectiveness. Indeed, only four units in the price sample had media saturation effectiveness greater than 0.9, all of which were Coolerado brand products with very low capacity. Due to these dynamics, the study team included CFM and brand in the final model specification for indirect evaporative coolers as shown below in Table 3-17.

Table 3-17: Hedonic Price Model Results for Nonresidential HVAC, Water Heating, and Shell

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
Fan VFDs (>10hp)	Size (horsepower)	Continuous	1 -100	48.28	18.16	2.650	N/A	45.820	N observations
	Manufacturer	Categorical	ABB	2230.89	13.00	171.630	N/A	171.630	98
			Siemens	0.00	--	--	N/A	--	N unit sales
	Bypass	Binary	Yes	789.74	3.25	242.700	N/A	242.700	Unknown
			No	0.00	--	--	N/A	--	R2
	NEMA enclosure type	Categorical	3r	927.75	4.36	212.920	N/A	212.920	0.872
			12	485.22	2.74	176.850	N/A	176.850	Intercept
			1	0.00	--	--	N/A	--	-139.760
									MAE
									389.300
									Contr. Markup
									0.20
Fan VFDs (<= 10hp)	Size (horsepower)	Continuous	1 -100	38.75	11.21	3.450	N/A	47.970	N observations
	Manufacturer	Categorical	ABB	447.68	14.54	30.790	N/A	30.790	86
			Siemens	0.00	--	--	N/A	--	N unit sales
	Bypass	Binary	Yes	283.54	2.80	101.350	N/A	101.350	Unknown
			No	0.00	--	--	N/A	--	R2
	NEMA enclosure type	Categorical	3r	1020.35	34.53	29.550	N/A	29.550	0.964
			12	248.59	8.44	29.450	N/A	29.450	Intercept
			1	0.00	--	--	N/A	--	291.130
	500 volts	Binary	Yes	114.46	4.52	25.310	N/A	25.310	MAE
			No	0.00	--	--	N/A	--	71.270
									Contr. Markup
									0.20

Table 3-17: Hedonic Price Model Results for Nonresidential HVAC, Water Heating, and Shell (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
Demand Control Ventilation	Temperature Sensor	Binary	Yes	51.04	5.53	9.236	N/A	51.037	N observations
			No	0.00	--	--	N/A	0.000	778
	Digital Display	Binary	Yes	72.81	10.42	6.986	N/A	72.811	N unit sales
			No	0.00	--	--	N/A	0.000	Unknown
	VOC Sensor	Binary	Yes	12.08	0.58	20.959	N/A	12.084	R2
			No	0.00	--	--	N/A	0.000	0.873
	Humidity Sensor	Binary	Yes	144.19	19.72	7.311	N/A	144.186	Intercept
			No	0.00	--	--	N/A	0.000	78.503
	Location	Categorical	Not Specified	0.00	--	--		0.000	MAE
			Duct	139.43	3.34	41.771	N/A	139.431	65.558
			Wall	74.15	1.77	41.968	N/A	74.151	Contr. Markup
	Manufacturer	Categorical	AirSense	-131.47	-8.41	15.635	0.095	157.213	0.15
			Airtest	49.42	2.18	22.660	0.026		
			BAPI	-73.55	-5.36	13.729	0.113		
			Carrier	41.34	0.72	57.711	0.006		
			Dwyer	26.16	1.60	16.401	0.158		
			GE	106.13	7.59	13.977	0.054		
			Honeywell	344.90	6.68	51.601	0.099		
			Johnson Controls	-30.21	-2.01	14.997	0.004		
			Kele	122.74	5.17	23.754	0.138		
			SenseAir	734.55	31.17	23.566	0.021		
			Siemens	100.90	1.61	62.719	0.022		
			Trane	178.67	7.06	25.302	0.003		
			Vaisala	373.68	34.72	10.762	0.021		
			Veris	373.61	34.78	10.740	0.242		
Direct Evaporative Coolers (non-residential)	Media Saturation Effectiveness	Continuous	0.72-0.9	1959.11	4.44	441.116	N/A	1959.111	N observations
	CFM @ 0.3" s.p.	Continuous	359-16,309	0.11	14.78	0.007	N/A	0.108	34
	Manufacturer	Categorical	Aerocool Pro	80.83	0.76	106.275	0.235	-97.634	N unit sales
			Aerocool Trophy	-179.99	-2.25	80.069	0.294		Unknown
			Brisa	-77.39	-1.01	76.605	0.147		R2
			Champion Cooler	-51.13	-0.53	97.321	0.088		0.977
			Frigiking	-312.99	-4.14	75.565	0.176		Intercept
			Mastercool	252.00	2.52	100.199	0.029		-834.691
			Phoenix	0.00	--	--	0.029		MAE
									47.272
									Contr. Markup
									0.25

Table 3-17: Hedonic Price Model Results for Nonresidential HVAC, Water Heating, and Shell (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
Indirect Evaporative Coolers	Rated Capacity (cfm)	Continuous	900-60000	2.13	43.17	0.049	N/A	2.129	N observations
	Heating Mode	Binary	Yes	12,215	9.57	1,277	N/A	12,215	201
			No	0.00	--	--	N/A	0.000	N unit sales
	Brand	Categorical	Coolerado	7,300	2.95	2,477	0.060	-18,767	Unknown
			Munters	-22,683	-12.16	1,866	0.836		R2
			Aztec	-16,311	-4.19	3,894	0.015		0.944
			WestAire	0	.	.	0.090		Intercept
									20,995
									MAE
									4,129
									Contr. Markup
									0.30
Small Packaged DX (<= 5 tons)	SEER	Continuous	13 - 17	289.41	6.08	47.637	N/A	289.414	N observations
	Capacity (BtuH)	Continuous	24,000-60,000	0.03	6.43	0.004	N/A	0.026	41
	Phase	Binary	1	0.00	--	--	0.585	16.284	N unit sales
			3	39.27	0.31	125.023	0.415		Unknown
	Voltage	Binary	208	0.00	--	--	0.805	28.239	R2
			460	144.72	1.09	132.988	0.195		0.894
	Manufacturer	Categorical	Carrier	-80.57	-0.57	141.811	0.000	-12.128	Intercept
			Lennox	-791.32	-5.10	155.028	0.015		-2,295
			Trane	0.00	--	--	0.176		MAE
									185
									Contr. Markup
									0.25
Large Packaged DX (> 5 tons)	EER	Continuous	9.5-13	2,312	2.02	1147.407	N/A	2,312	N observations
	Capacity (BtuH)	Continuous	83,000-1,270,420	0.08	27.45	0.003	N/A	0.080	43
	Voltage	Binary	208	0.00	--	--	0.186	-1,496	N unit sales
			460	-1,837	-0.77	2392.105	0.814		Unknown
	Gas Heat Option	Binary	Yes	-2,207	-1.07	2064.925	0.395	-872	R2
			No	0.00	--	--	0.605		0.982
	Manufacturer	Categorical	Carrier	-65.42	-0.03	2399.132	0.395	1,351	Intercept
			McQuay	6,580	1.79	3669.405	0.209		-26,555
			Trane	0.00	--	--	0.395		MAE
									2,802
									Contr. Markup
									0.20

Table 3-17: Hedonic Price Model Results for Nonresidential HVAC, Water Heating, and Shell (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
Air-Cooled Chillers	Capacity (tons)	Continuous	45-400	505	40.67	12.414	N/A	505	N observations
	kW/ton	Continuous	1.054-1.25	-113,083	-5.19	21,775	N/A	-113,083	37
	Compressor type	Categorical	Screw	0.00	--	--	N/A	0.000	N unit sales
			Scroll	2,118	0.77	2,736	N/A	2,118	Unknown
			Reciprocating	N/A	N/A	N/A	N/A	N/A	R2
	Manufacturer	Categorical	Carrier	4,254	1.86	2,288	0.162	-4,130	0.988
			Trane	-18,678	-6.75	2,768	0.258		Intercept
			York	0.00	--	--	0.052		136,264
									MAE
									3,788
									Contr. Markup
									0.25
Water-Cooled Chillers (excluding centrifugal VSD)	Capacity (tons)	Continuous	59.9-550	251.29	8.45	29.740	N/A	251	N observations
	kW/ton	Continuous	0.478-0.769	-200,330	-3.52	56,926	N/A	-200,330	48
	Compressor type	Categorical	Centrifugal	-18,496	-2.93	6,310	N/A	-18,496	N unit sales
			Screw	0.00	--	--	N/A	0.000	Unknown
			Scroll	-4,316	-0.58	7,473	N/A	-4,316	R2
			Reciprocating	N/A	N/A	N/A	N/A	N/A	0.906
									Intercept
									163,883
									MAE
									10,905
									Contr. Markup
									0.20
Water-Cooled Centrifugal VSD Chillers (>= 300 tons)	Capacity (tons)	Continuous	300-1500	443	27.36	16	N/A	443	N observations
	kW/ton	Continuous	0.518-0.596	-448,127	-1.99	224,690	N/A	-448,127	23
	Manufacturer	Categorical	Carrier	-3,328	-0.30	11,015	0.254	-3,218	N unit sales
			Trane	-9,845	-0.59	16,807	0.241		Unknown
			York	0.00	.	.	0.139		R2
									0.988
									Intercept
									240,852
									MAE
									15,465
									Contr. Markup
									0.20

Table 3-17: Hedonic Price Model Results for Nonresidential HVAC, Water Heating, and Shell (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
Small Packaged HP (< 65,000 Btuh)	Rated Capacity (Btuh)	Continuous	24000-60000	0.02	5.69	0.004	N/A	0.025	N observations
	SEER	Continuous	13-15	355	3.64	97	N/A	355	34
	Brand	Categorical	JCI	3,062	9.85	311	0.000	176	N unit sales
			Lennox	-527	-3.22	164	0.033		Unknown
			Carrier	751	3.85	195	0.257		R2
			Trane	0	.	.	0.112		0.941
									Intercept
									-2,913
									MAE
									182
									Contr. Markup
									0.20
Large Packaged HP (65,000 - 240,000 Btuh)	Rated Capacity (Btuh)	Continuous	72000-240000	0.09	10.44	0.009	N/A	0.089	N observations
	EER	Continuous	9.7-12.6	1623.76	1.99	813.925	N/A	1623.761	39
	Power exhaust	Binary	No	-6775.37	-5.07	1337.594	0.872	-5906.737	N unit sales
			Yes	0.00	--	--	0.128		Unknown
	Distributor	Categorical	US Air Distributors	-5622.18	-4.44	1264.846	0.179	-3133.898	R2
			JCI	-513.25	-0.33	1567.930	0.077		0.873
			Siglers	-5020.27	-4.68	1072.695	0.359		Intercept
			Unspecified	0.00	.	.	0.231		-9,330
			Pacific Coast Trane	-1840.55	-1.37	1345.267	0.154		MAE
									1,574
									Contr. Markup
									0.20
Steam Boilers (non-process)	Rated Capacity (kBtuh)	Continuous	250-3188	13.30	5.36	2.481	N/A	13.305	N observations
	Efficiency	Continuous	0.8-0.85	417095.99	2.25	185461.31 1	N/A	417095.989	22
	Brand	Categorical	Fulton	30808.03	4.83	6377.892	0.040	6196.077	N unit sales
			Parker	32634.82	3.61	9029.176	0.152		Unknown
			Smith	11676.45	1.76	6652.195	0.000		R2
			Ajax	0.00	--	--	0.011		0.775
									Intercept
									-341,928
									MAE
									6,021
									Contr. Markup
									0.20

Table 3-17: Hedonic Price Model Results for Nonresidential HVAC, Water Heating, and Shell (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
Waterside Economizers	Capacity (tons)	Continuous	100-750	85.73	14.26	6.010	N/A	85.732	N observations
	Brand	Categorical	GEA	0.00	-	-	0.513	-8026.673	39
			TACO	-16475.80	-6.06	2720.136	0.487		N unit sales
									Unknown
									R2
									0.866
									Intercept
									13,406
									MAE
									6,179
									Contr. Markup
									0.20
Large Storage Gas WH (> 75,000 BtuH and TE rated)	Rated Input (Btuh)	Continuous	75,100-740,000	0.01	8.23	0.00	N/A	0.011	N observations
	Rated Volume (gallons)	Continuous	50-130	29.92	2.77	10.80	N/A	29.923	65
	Thermal Efficiency	Continuous	0.79-0.99	11,363	3.95	2,878	N/A	11,363	N unit sales
	ASME Construction	Binary	Yes	945.49	2.55	370.60	0.385	363.649	Unknown
			No	0.00	--	--	0.615		R2
	Supplier	Categorical	Cal Steam	3,779	2.58	1,464	0.677	2,565	0.876
			Pace Supply	0.00	--	--	0.077		Intercept
			Heieck Supply	0.00	--	--	0.015		-11,575
			Ferguson Plumbing Supply	30.75	0.02	1473.03	0.231		MAE
	Manufacturer	Categorical	AO Smith	74.07	0.05	1407.29	0.000	0.000	862.791
			State Industries	0.00	--	--	0.000		Contr. Markup
									0.15
SHW Boilers (< 300 kBtuh, non-condensing)	Rated Capacity (kBtuh)	Continuous	90-238	13.55	3.50	3.87	N/A	13.550	N observations
	Efficiency (AFUE)	Continuous	0.83-0.85	111,174	3.81	29,150	N/A	111,174	8
									N unit sales
									N/A
									R2
									0.855
									Intercept
									-92,570
									MAE
									331.475
									Contr. Markup
									0.30

Table 3-17: Hedonic Price Model Results for Nonresidential HVAC, Water Heating, and Shell (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	**Type**	**Values**	**Coefficient**	**t-stat**	**Standard Error**	**Roll-up Wts**	**Wtd Coefficient**	
SHW Boilers (> 300 kBtuh, non-condensing)	Rated Capacity (kBtuh)	Continuous	300-4000	13.54	7.04	1.92	N/A	13.535	N observations
	Efficiency	Continuous	0.82-0.88	505,493	2.77	182,774	N/A	505,493	34
	Brand	Categorical	Ajax	-256	-0.02	10,290	0.000	93.503	N unit sales
			Camus	-11,736	-1.18	9,956	0.000		Unknown
			Laars	4,010	0.41	9,826	0.000		R2
			PK	19,232	1.74	11,057	0.005		0.913
			RBI	-13,277	-1.39	9,570	0.000		Intercept
			Unspecified	0	--	--	0.000		-419,978
			Viessmann	697	0.05	13,840	0.000		MAE
									2650.801
									Contr. Markup
									0.30
SHW Boilers (condensing)	Rated Capacity (kBtuh)	Continuous	67-4000	9.87	8.06	1.22	N/A	9.865	N observations
	Efficiency	Continuous	0.90-0.96	143,589	2.90	49,588	N/A	143,589	38
	Brand	Categorical	Camus	8,707	3.29	2,649	0.000	231	N unit sales
			Laars	9,334	4.20	2,224	0.019		Unknown
			PK	10,693	5.99	1,785	0.005		R2
			Raypak	-778	-0.39	2,000	0.000		0.943
			Viessmann	0	--	--	0.000		Intercept
									-129,921
									MAE
									2196.163
									Contr. Markup
									0.30
Thermal Curtain	Flame Retardant	Binary	Yes	0.19	8.98	0.02	N/A	0.190	N observations
			No	0.00	--	--	N/A	0.000	37
	Contains Aluminum	Binary	Yes	0.20	8.87	0.02	N/A	0.198	N unit sales
			No	0.00	--	--	N/A	0.000	Unknown
	Performance/Purpose	Categorical	Blackout	0.21	7.21	0.03	N/A	0.206	R2
			Energy Savings & Solar Reflection	0.07	2.72	0.02	0.833	0.059	0.846
			Energy Savings	0.03	0.71	0.04	0.167		Intercept
			Supplemental Light	0.11	1.78	0.06	N/A	0.111	0.002
			Solar Reflection	0.00	--	--	N/A	0.000	MAE
									0.040
									Contr. Markup
									0.50

Table 3-17: Hedonic Price Model Results for Nonresidential HVAC, Water Heating, and Shell (continued)

Technology	Model Variables			Model Results					Model Stats
	Name	Type	Values	Coefficient	t-stat	Standard Error	Roll-up Wts	Wtd Coefficient	
Reflective Film	Emissivity	Continuous	0.07 -0.91	-3.15	4.02	0.79	N/A	-3.150	N observations
	Glare Reduction	Continuous	0.16 - 0.94	-3.67	4.48	0.82	N/A	-3.670	30
	Solar Heat Gain Coefficient	Continuous	0.16 - 0.82	2.39	2.26	1.06	N/A	2.390	N unit sales
	Visible Light Reflected Exterior	Continuous	9 - 80	0.06	5.78	0.01	N/A	0.062	Unknown
	Visible Light Reflected Interior	Continuous	9 - 64	0.03	3.55	0.01	N/A	0.031	R2
	Winter U Value	Continuous	0.59 - 5.91	0.16	3.02	0.05	N/A	0.164	0.848
									Intercept
									3.510
									MAE
									0.448
									Contr. Markup
									0.00

3.5.4 Roll-up Weights

The price models developed for nonresidential HVAC, water heating, and shell measures included statistically significant relationships between brand and price for multiple technologies. In order to aggregate these brand effects into market-averages, the study team developed roll-up weights using recent brand distributions from the most recent market share data available as described below. It should be noted that the estimated effect of brand on unit prices for nonresidential HVAC, water heating, and shell measures also likely captures price variations related to distributor pricing practices and the fact that individual distributors tend to carry a selection of brands rather than the entire population of brands.

To develop brand weights for small packaged DX and HPs, the study team leveraged the brand distributions observed from the on-site surveys of recent equipment purchasers recently conducted for the Commercial Market Share Tracking Study (CMST) (WO24). These brand distributions compared well against the larger on-site survey sample collected for the Commercial Saturation Survey (CSS) (WO24), i.e. the brand distribution of newer equipment compared well to the brand distribution from all in-situ equipment. For large storage water heaters, the study team leveraged the brand distributions observed from the on-site surveys recently conducted for California Lighting and Appliance Saturation Survey (CLASS) (WO21), using an age flag in that dataset that allowed brand distributions to be estimated only for the cohort of equipment installed since 2006.

For chillers and boilers, the most recent California market share data available to the study team was from the 2006 California Commercial End-Use Survey (CEUS) study, for which data was collected primarily in 2004. The study team believes it is reasonable to use 2004 vintage data as a proxy for current marginal brand shares given the long service life of these types of capital equipment and little change in the manufacturer mix since the time the CEUS data was collected.

For large packaged DX, only one brand had a statistically significant effect on price (McQuay), but this brand was not present in either the CSS or CMST survey samples. For DCV, direct and indirect evaporative coolers, and water-side economizers, neither CSS, CMST, CLASS nor CEUS collected the brand information required to develop roll-up weights. In these cases, the study team used the brand shares in the price sample (by technology) as proxies for market shares.

3.5.5 Model Results and Findings

Table 3-18 presents the study team's estimates of incremental equipment prices for nonresidential HVAC, water heating, and shell measures. Note that these tables exclude the incremental price estimates for chillers and boilers, which are presented separately in Table 3-19 and Table 3-20, respectively.[26]

For packaged DX and HPs (small and large), predicted unit equipment prices for both baseline and high-efficiency units validate well compared to a combination of unit price estimates from small samples of artificial project bids, previous DEER estimates, IOU workpaper estimates, and RSMeans. For small packaged DX (less than 5 tons), the incremental cost estimates are in line with the DEER 2008 estimate. However, strict comparisons are difficult since only a broad capacity range is defined in DEER 2008 (less than 65 kbtuh) – which implies that the study team's estimated incremental cost is higher than previous DEER for 1-2 ton units but lower for 4-5 ton units. For small packaged HPs (less than 5 tons), predicted unit prices are consistent with those in DEER 2005, but incremental costs are roughly twice those estimated in DEER 2005.[27] For large packaged DX and HPs (greater than 5 tons), predicted unit prices validate well compared to artificial project bids but are systematically higher than previous DEER estimates, particularly for units 20 tons and over. Nonetheless, the study team's incremental cost estimates for large packaged DX are slightly lower than those from DEER 2008.[28]

For large storage gas water heaters, predicted unit prices and incremental costs compare well to those from DEER 2008. In contrast, the study team's predicted unit prices are systematically higher (by ~20%) compared to a small sample of online retailer price lookups, particularly for baseline efficiency units. It should be noted, however, that within the validation dataset, prices for a given product description vary by 30-50%, which may indicate high sensitivity to contractor-retailer markups, bulk purchase discounts, and other markup practices along the supply chain.

For fan VFDs, predicted unit prices compare well to a small sample of online retailer price lookups across a variety of product specifications (e.g. HP and NEMA enclosure type) but are generally ~10 percent higher than advertised prices. Compared to DEER 2008, predicted unit prices are much lower ($60-116/HP compared to $176/HP). However, strict comparisons are difficult since the study team estimated separate models for <10 HP units and 10+ HP units and also controlled for the (significant) price impacts of NEMA enclosure type and other product features not currently specified in DEER and the IOU workpapers.

[26] The complete set of incremental cost estimates based on the measure definitions from READI v.1.0.4 "Draft Combined DEER 2011 and DEER 2014 plus IOU Ex Ante for the 2013-14 Cycle" is provided in Appendix F.

[27] Small packaged HPs were not included in the DEER 2008 update.

[28] The incremental cost estimates for large packaged HPs are not strictly comparable to those from DEER 2008, as both the baseline and measure efficiency levels have since changed, and incremental costs for current baseline-measure efficiency increments were not previously estimated.

For direct evaporative coolers, predicted unit prices compare well to DEER 2001 estimates, as well as those from the IOU workpapers and RSMeans. For indirect evaporative coolers, however, predicted unit prices are significantly higher than all previous DEER estimates (2001, 2005, and 2008). It should be noted, however, that these comparisons are based on rough CFM-to-tons-cooling conversions, since previous DEER estimates were all expressed on a per-ton cooling basis.[29] Additionally, the study team's model results are consistent with the raw unit price data, which were thoroughly vetted with distributors.

For waterside economizers, predicted unit prices compare well to artificial project bids but are significantly higher than DEER 2005 estimates. It should be noted, however, that the DEER 2005 estimates include costs for piping, valves, and installation labor.[30] When the study team's estimates of non-equipment installation costs (i.e. labor and piping) are added to predicted unit prices, the total estimated installed cost compares very well to the aggregate DEER 2005 estimates.

For DCV, there were very few benchmarks against which to validate predicted unit prices, as no previous DEER estimates exist for this technology. SCE's "enhanced ventilation" measure includes DCV, but the measure cost estimated presented in SCE's associated workpaper is an aggregate of the CO_2 sensor and adding a VFD on the supply fan motor. Since the study team's unit price estimates only reflect the price of the CO_2 sensor, the measure costs in SCE's workpaper for "enhanced ventilation" are not strictly comparable.

For reflective film, predicted unit prices are consistent with those in DEER 2008 ($1.98/ft^2), although the study team's price estimates vary from $1-2/ft2 depending on a variety of product specifications such as emissivity, winter U-value, and SHGC. For thermal curtains, predicted unit prices were difficult to validate. Only one of the artificial bid responses included material costs disaggregated from installation labor costs – for which the unit material costs were consistent with a 50 percent markup of the predicted unit price.

29 Strictly speaking, converting CFM to tons cooling equivalent requires knowing the temperature differential between indoor and outdoor air, as well as the technical specifications of the HVAC systems. Actual CFM to tons cooling ratios can vary by ±30% or more.

30 See section 3.2.3.

Table 3-18: Incremental Equipment Price Estimates for Nonresidential HVAC, Water Heating, and Shell (Excluding Chillers and Boilers)

Technology	Measure Source	Match Pair	Description	Modeled Price	IMC
Fan VFDs (>10hp)	Workpaper Measures	Baseline	Absence of VFD. Baseline is throttling valves, inlet vanes and fan dampers	-	-
		Measure	VFD Supply Fan Motors (Siemens,20hp, nema 12 enclosure, no bypass)	$2,087.89	$2,087.89
		Measure	VFD Supply Fan Motors (Siemens,30hp, nema 1 enclosure, no bypass)	$2,055.47	$2,055.47
		Measure	VFD Supply Fan Motors (Siemens,40hp, nema 3 enclosure, with bypass)	$4,666.29	$4,666.29
		Measure	VFD Supply Fan Motors (Siemens,60hp, nema 12 enclosure, no bypass)	$4,287.25	$4,287.25
		Measure	VFD Supply Fan Motors (Siemens,75hp, nema 12 enclosure, no bypass)	$5,112.01	$5,112.01
		Measure	VFD Supply Fan Motors (Siemens,100hp, nema 1 enclosure, no bypass)	$5,904.35	$5,904.35
		Measure	VFD Supply Fan Motors (Siemens,50hp, nema 1 enclosure, no bypass)	$3,155.15	$3,155.15
Fan VFDs (<= 10hp)	Workpaper Measures	Baseline	Absence of VFD. Baseline is throttling valves, inlet vanes and fan dampers	-	-
		Measure	VFD Supply Fan Motors (Siemens,1.5hp, nema 12 enclosure, no bypass)	$827.71	$827.71
		Measure	VFD Supply Fan Motors (Siemens,5hp, nema 1 enclosure, no bypass)	$730.88	$730.88
		Measure	VFD Supply Fan Motors (Siemens,10hp, nema 1 enclosure, no bypass)	$1,018.70	$1,018.70
		Measure	VFD Supply Fan Motors (Siemens,10hp, nema 3r enclosure, no bypass)	$2,243.12	$2,243.12
Demand Control Ventilation	Example Measures	Measure	Duct Mounted unit	$431.42	$431.42
		Measure	Duct Mounted unit with Digital Display and VOC Sensor	$529.05	$529.05
		Measure	Duct Mounted unit with Humidity Sensor	$597.23	$597.23
		Measure	Duct Mounted unit with Temperature Sensor	$490.11	$490.11
		Measure	Wall Mounted unit	$356.35	$356.35
		Measure	Wall Mounted unit with Digital Display	$440.08	$440.08
		Measure	Wall Mounted unit with Humidity Sensor	$522.16	$522.16
		Measure	Wall Mounted unit with Temperature Sensor	$415.04	$415.04
		Measure	Wall Mounted unit with Temperature Sensor and Digital Display	$498.77	$498.77
		Measure	Wall Mounted unit with Temperature Sensor and Humidity Sensor	$580.85	$580.85
		Measure	Wall Mounted unit with Temperature Sensor, Digital Display, and Humidity Sensor	$664.59	$664.59

Table 3-18: Incremental Equipment Price Estimates for Nonresidential HVAC, Water Heating, and Shell (Excluding Chillers and Boilers) (continued)

Technology	Measure Source	Match Pair	Description	Modeled Price	IMC
Direct Evaporative Coolers (non-residential)	Example Measures	Baseline	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner (for PG&E ROB measures) assumed 2 ton	$1,268.55	-
		Baseline	For SCE measures, evap coolers are add-on measures to existing DX systems	-	-
		Measure	2,340 CFM, 0.85 media saturation effectiveness (~2 ton equivalent)	$1,232.89	$1,232.89
		Measure	3,510 CFM, 0.87 media saturation effectiveness (~3 ton equivalent)	$1,440.24	$1,440.24
		Measure	5,850 CFM, 0.9 media saturation effectiveness (~5 ton equivalent)	$1,830.44	$1,830.44
		Measure	11,700 CFM, 0.9 media saturation effectiveness (~10 ton equivalent)	$2,622.29	$2,622.29
		Measure	17,550 CFM, 0.9 media saturation effectiveness (~15 ton equivalent)	$3,414.14	$3,414.14
Indirect Evaporative Coolers	DEER Measures	Baseline	Absence of indirect evaporative cooling on T24-compliant HVAC system	-	-
		Measure	Indirect evap cooling for make-up air only, 65% effectiveness assumed 3,000 cfm, no gas heat	$11,201.38	$11,201.38
	Example Measure	Measure	Indirect evap cooling for make-up air only, 65% effectiveness assumed 45,000 cfm, no gas heat	$127,465.53	$127,465.53
Small Packaged DX (<= 5 tons)	DEER Measures	Baseline	Pkg AC SEER = 13.00; EER = 11.06; Clg EIR = 0.256; Supply Fan W/cfm = 0.379; no econo assumed 2 ton	$2,650.32	-
		Measure	Pkg AC SEER = 14.0 (< 65 kBtuh), EER = 11.06, Clg EIR = 0.2557, Supply Fan W/cfm = 0.379 assumed 2 ton	$3,012.09	$361.77
		Baseline	Pkg AC SEER = 13.00; EER = 11.06; Clg EIR = 0.256; Supply Fan W/cfm = 0.379; no econo assumed 5 ton	$3,814.47	-
		Measure	Pkg AC SEER = 14.0 (< 65 kBtuh), EER = 12.04, Clg EIR = 0.2456, Supply Fan W/cfm = 0.306 assumed 5 ton	$4,176.24	$361.77

Table 3-18: Incremental Equipment Price Estimates for Nonresidential HVAC, Water Heating, and Shell (Excluding Chillers and Boilers) (continued)

Technology	Measure Source	Match Pair	Description	Modeled Price	IMC
Large Packaged DX (> 5 tons)	DEER Measures	Baseline	Pkg AC EER = 10.80; Clg EIR = 0.262; Supply Fan W/cfm = 0.269514; Cond Fan W/Btuh = 0.00535136; w/ econo assumed 187 kBtuh	$14,805.80	-
		Measure	Pkg AC EER = 11.5 (135-239 kBtuh), Clg EIR = 0.2439, Supply Fan W/cfm = 0.233, Cond Fan W/Btuh = 0.0064 assumed 187 kBtuh	$16,748.07	$1,942.27
		Measure	Pkg AC EER = 12.0 (135-239 kBtuh), Clg EIR = 0.2307, Supply Fan W/cfm = 0.165, Cond Fan W/Btuh = 0.0089 assumed 187 kBtuh	$18,135.41	$3,329.61
		Baseline	Pkg AC EER = 9.80; w/ furnace; w/ econo assumed 500 kBtuh	$42,034.06	-
		Measure	Pkg AC EER = 10.5 (240-759 kBtuh) assumed 500 kBtuh	$43,976.33	$1,942.27
		Measure	Pkg AC EER = 10.8 (240-759 kBtuh) assumed 500 kBtuh	$44,808.73	$2,774.67
		Baseline	Pkg AC EER = 11.00; Clg EIR = 0.257; Supply Fan W/cfm = 0.298; Cond Fan W/Btuh = 0.0053; no econo assumed 77 kBtuh	$4,816.58	-
		Measure	Pkg AC EER = 11.5 (65-89 kBtuh), Clg EIR = 0.2401, Supply Fan W/cfm = 0.248, Cond Fan W/Btuh = 0.0060 assumed 77 kBtuh	$6,203.91	$1,387.34
		Measure	Pkg AC EER = 12.0 (65-89 kBtuh), Clg EIR = 0.2304, Supply Fan W/cfm = 0.238, Cond Fan W/Btuh = 0.0057 assumed 77 kBtuh	$7,591.25	$2,774.67
		Baseline	Pkg AC EER = 11.00; Clg EIR = 0.257; Supply Fan W/cfm = 0.298; Cond Fan W/Btuh = 0.0053; w/ econo assumed 112 kBtuh	$8,171.54	-
		Measure	Pkg AC EER = 11.5 (90-134 kBtuh), Clg EIR = 0.2401, Supply Fan W/cfm = 0.248, Cond Fan W/Btuh = 0.0060 assumed 112 kBtuh	$9,558.87	$1,387.34
		Measure	Pkg AC EER = 12.0 (90-134 kBtuh), Clg EIR = 0.2304, Supply Fan W/cfm = 0.238, Cond Fan W/Btuh = 0.0057 assumed 112 kBtuh	$10,946.21	$2,774.67
		Baseline	Pkg AC EER = 9.50; w/ furnace; w/ econo assumed 760 kBtuh	$66,124.22	-
		Measure	Pkg AC EER = 10.2 (>= 760 kBtuh) assumed 760 kBtuh	$68,066.49	$1,942.27
		Measure	Pkg AC EER = 9.7 (>= 760 kBtuh) assumed 760 kBtuh	$66,679.15	$554.93

Table 3-18: Incremental Equipment Price Estimates for Nonresidential HVAC, Water Heating, and Shell (Excluding Chillers and Boilers) (continued)

Technology	Measure Source	Match Pair	Description	Modeled Price	IMC
Small Packaged HP (< 65,000 Btuh)	DEER Measures	Baseline	Pkg HP SEER = 13.0 (< 65 kbtuh) assumed 40,000 btuh capacity	$3,446.57	-
		Measure	Pkg HP SEER = 14.0 (< 65 kbtuh), EER = 11.6, HSPF = 8.00, COP = 3.52 assumed 40,000 btuh capacity	$3,872.46	$425.89
		Measure	Pkg HP SEER = 15.0 (< 65 kbtuh), EER = 12.0, HSPF = 8.50, COP = 3.74 assumed 40,000 btuh capacity	$4,298.35	$851.78
		Measure	Pkg HP SEER = 14.5 (< 65 kBtuh) - Combined SEER 14 and SEER 15 hp assumed 40,000 btuh capacity	$4,085.40	$638.83
Large Packaged HP (65,000 - 240,000 Btuh)	DEER Measures	Baseline	Pkg HP EER = 10.6 assumed 187 kBtuh capacity	$18,560.52	-
		Measure	Pkg HP EER = 11.5 (135-239 kBtuh), COP = 3.2 assumed 187 kBtuh capacity	$20,314.18	$1,753.66
		Measure	Pkg HP EER = 12.0 (135-239 kBtuh), COP = 3.2 assumed 187 kBtuh capacity	$21,288.44	$2,727.92
		Baseline	Pkg HP EER = 11.0 assumed 77 kBtuh capacity	$7,604.20	-
		Measure	Pkg HP EER = 11.5 (65-89 kBtuh), COP = 3.4 assumed 77 kBtuh capacity	$8,578.46	$974.26
		Measure	Pkg HP EER = 12.0 (65-89 kBtuh), COP = 3.4 assumed 77 kBtuh capacity	$9,552.71	$1,948.51
		Baseline	Pkg HP EER = 11.0 assumed 112 kBtuh capacity	$11,338.29	-
		Measure	Pkg HP EER = 11.5 (90-134 kBtuh), COP = 3.4 assumed 112 kBtuh capacity	$12,312.55	$974.26
		Measure	Pkg HP EER = 12.0 (90-134 kBtuh), COP = 3.4 assumed 112 kBtuh capacity	$13,286.81	$1,948.51
Waterside Economizers	DEER Measure	Baseline	T24 minimum: no water economizer	-	-
	Example Measures	Measure	Non-integrated evaporator precooler heat exchanger assumed 100 ton capacity	$16,743.13	$16,743.13
		Measure	Non-integrated evaporator precooler heat exchanger assumed 200 ton capacity	$27,030.96	$27,030.96
		Measure	Non-integrated evaporator precooler heat exchanger assumed 300 ton capacity	$37,318.79	$37,318.79
		Measure	Non-integrated evaporator precooler heat exchanger assumed 400 ton capacity	$47,606.62	$47,606.62
		Measure	Non-integrated evaporator precooler heat exchanger assumed 500 ton capacity	$57,894.45	$57,894.45
		Measure	Non-integrated evaporator precooler heat exchanger assumed 600 ton capacity	$68,182.29	$68,182.29
		Measure	Non-integrated evaporator precooler heat exchanger assumed 700 ton capacity	$78,470.12	$78,470.12
Large Storage Gas WH (> 75,000 BtuH and TE rated)	DEER Measures	Baseline	Large Gas Storage Water Heater; Et = 0.80; Stdby Loss = 0.56%/hr assumed 75 gal capacity and 125,000 Btuh	$4,885.99	-
		Measure	High Efficiency Large Gas Storage Water Heater - 0.83 Et assumed 75 gal capacity and 125,000 Btuh	$5,105.96	$219.96
		Measure	High Efficiency Large Gas Storage Water Heater - 0.90 Et assumed 75 gal capacity and 125,000 Btuh	$6,020.67	$1,134.68

Table 3-18: Incremental Equipment Price Estimates for Nonresidential HVAC, Water Heating, and Shell (Excluding Chillers and Boilers) (continued)

Technology	Measure Source	Match Pair	Description	Modeled Price	IMC
Thermal Curtains	Example Measures	Baseline	Absence of Thermal Curtain	-	-
		Measure	Flame Retardant, Contains Aluminum, Solar Reflection	$0.59	$0.59
		Measure	Flame Retardant, No Aluminum, Solar Reflection	$0.29	$0.29
		Measure	Flame Retardant, No Aluminum, Supplemental Lighting	$0.17	$0.17
		Measure	No Flame Retardant, Contains Aluminum, Solar Reflection	$0.30	$0.30
		Measure	No Flame Retardant, Contains Aluminum, Blackout	$0.61	$0.61
		Measure	No Flame Retardant, No Aluminum, Blackout	$0.31	$0.31
Reflective Film	Workpaper Measures	Baseline	Absence of window film in window with .82 SHGC	-	-
		Measure	Window film (0.37 SHGC) assumed 0.81 emissivity, 0.63 glare reduction, 1.03 winter U-value	$1.10	$1.10
		Measure	Window film (0.29 SHGC) assumed 0.84 emissivity, 0.64 glare reduction, 5.91 winter U-value	$1.46	$1.46
		Measure	Window film (0.22 SHGC) assumed 0.71 emissivity, 0.80 glare reduction, 0.97 winter U-value	$1.10	$1.10
		Measure	Window film (0.17 SHGC) assumed 0.84 emissivity, 0.91 glare reduction, 5.91 winter U-value	$2.23	$2.23

Table 3-19 and Table 3-20 present the incremental price estimates for chillers and boilers. These results are presented separately from the nonresidential HVAC, water heating, and shell measure presented above due to the capital-intensive nature of chiller and boiler investments and corresponding difficulty assessing the accuracy of predicted prices that can range well above $100,000 per unit. For this reason,

Table 3-19 and Table 3-20 present both the predicted unit price and incremental cost normalized against capacity (tons). Additionally, these tables explicitly show the specific efficiency differential associated with each incremental cost estimate, i.e. ΔkW/ton for chillers, Δ percent thermal efficiency or Δ percent AFUE for boilers, in order to better see how estimated incremental costs vary with capacity.

For chillers, as mentioned previously, the relationships between price, capacity, and efficiency should ideally be analyzed for *each* type of compressor, e.g. scroll, screw, centrifugal, and VSD centrifugal. However, the final price samples assembled by the study team only supported segmenting the analysis by air-cooled vs. water-cooled chillers, and compressor type was specified as an independent variable within each of those models. In principle, because the range of capacities covered by the chiller models is very large and certain compressor types are only used within certain parts of that range, specifying compressor type as an independent variable within these models could cause unexpected results for certain capacity, efficiency, and compressor type combinations. However, within the most common (and in-sample) combinations, predicted unit prices and incremental costs generally validated well compared to previous DEER estimates, IOU workpaper estimates, artificial project bids, and RSMeans.[31]

For boilers, the final price samples assembled by the study team only supported segmenting the analysis by condensing, non-condensing (large and small), and steam boilers. For non-condensing SHW boilers, predicted prices and incremental cost estimates are largely consistent with previous DEER estimates.[32] One key exception, however, was that the study team found no statistically significant price differences related to atmospheric versus forced draft units, whereas previous DEER estimates showed significant price premiums for forced draft units on the order of 7-10 percent (for units larger than 1000 MBH).

It should also be noted that the study team had difficulty assembling a significant sample of prices for baseline efficiency (e.g. 82 percent thermal efficiency), non-condensing SHW and steam boilers in the 300-400 MBH capacity range. As such, the hedonic price models for large (e.g. 300 MBH and above) non-condensing SHW boilers and steam boilers do not perform well at the low end of the capacity and efficiency spectrums and predict negative prices for the smallest baseline efficiency units (i.e. 300 MBH, 82 percent thermal efficiency). However, the study team confirmed with equipment vendors that such low efficiency units are not available in many parts of the state.

[31] RSMeans and the artificial bids for chiller projects do not specify efficiency level or compressor type. However, the associated unit price estimates fell within those predicted by the study team's price models.

[32] No benchmark data was available from previous DEER, IOU workpapers, or RSMeans to validate the study team's predicted prices for condensing SHW boilers.

Table 3-19: Incremental Equipment Price Estimates for Chillers

Technology	Measure Source	Match Pair	Description	Modeled Price	IMC/ton	ΔkW/ ton
Air-Cooled Chillers	DEER Measures	Baseline	Air cooled package screw chiller (1.260 kW/ton) assumed 50 ton	$18,617.05 $372.34/ton	$712.43 / ton	0.252
		Measure	Air cooled screw chiller (1.008 kW/ton) assumed 50 ton	$54,238.32 $1,084.77/ton		
		Baseline	Air cooled package screw chiller (1.260 kW/ton) assumed 130 ton	$69,105.91 $532.58/ton	$274.01 / ton	0.252
		Measure	Air cooled screw chiller (1.008 kW/ton) assumed 130 ton	$104,727.18 $805.59/ton		
	Example Measures	Baseline	Air cooled package Scroll chiller (1.260 kW/ton) assumed 100 ton	$52,820.09 $528.20/ton	$356.21 / ton	0.252
		Measure	Air cooled Scroll chiller (1.008 kW/ton) assumed 100 ton	$88,441.35 $884.41/ton		
		Baseline	Air cooled package Scroll chiller (1.260 kW/ton) assumed 50 ton	$21,264.55 $425.29/ton	$712.43 / ton	0.252
		Measure	Air cooled Scroll chiller (1.008 kW/ton) assumed 50 ton	$56,885.82 $1,137.72/ton		
Water-Cooled Chillers (excluding centrifugal VSD)	DEER Measures	Baseline	Water cooled centrifugal chiller (0.634 kW/ton) assumed 175 ton	$74,824.21 $427.57 / ton	$174.46 / ton	0.127
		Measure	Water cooled centrifugal chiller (150-299 tons, 0.507 kW/ton) assumed 175 ton	$105,354.50 $602.03/ton		
		Baseline	Water cooled centrifugal chiller (0.576 kW/ton) assumed 300 ton	$126,461.05 $421.54/ton	$92.15 / ton	0.115
		Measure	Water cooled centrifugal chiller (>= 300 tons, 0.461 kW/ton) assumed 300 ton	$154,106.59 $513.69/ton		
		Baseline	Water cooled centrifugal chiller (0.700 kW/ton) assumed 100 ton	$36,341.76 $363.42/ton	$336.55/ ton	0.140
		Measure	Water cooled centrifugal chiller (< 150 tons, 0.560 kW/ton) assumed 100 ton	$69,997.19 $699.97/ton		
		Baseline	Water cooled screw chiller (0.718 kW/ton) assumed 225 ton	$91,904.07 $408.46/ton	$153.85/ ton	0.144
		Measure	Water cooled screw chiller (150-299 tons, 0.574 kW/ton) assumed 225 ton	$126,521.08 $562.32/ton		
		Baseline	Water cooled screw chiller (0.639 kW/ton) assumed 300 ton	$133,511.67 $445.04/ton	$102.57/ ton	0.128
		Measure	Water cooled screw chiller (>= 300 tons, 0.511 kW/ton) assumed 300 ton	$164,282.35 $547.61/ton		
		Baseline	Water cooled screw chiller (0.790 kW/ton) assumed 100 ton	$36,901.69 $369.02/ton	$379.83/ ton	0.158
		Measure	Water cooled screw chiller (< 150 tons, 0.632 kW/ton) assumed 100 ton	$74,884.25 $748.84/ton		
Water-Cooled Centrifugal VSD Chillers	DEER Measures	Baseline	Water cooled centrifugal chiller (0.573 kW/ton) assumed 500 tons	$187,492.44 $374.98/ton	$230.86 / ton	0.112
		Measure	Water cooled VSD centrifugal chiller (>= 300 tons, 0.461 kW/ton), load control tower assumed 500 tons	$302,924.30 $605.85/ton		

Table 3-20: Incremental Equipment Price Estimates for Boilers

Technology	Measure Source	Match Pair	Description	Modeled price	IMC / MBH	ΔAFUE /TE
SHW Boilers < 300 MBH, non-condensing	DEER Measures	Baseline	Hot water boiler (<300 MBH; 82.0% AFUE; atmospheric) assumed 250 MBH	$2,574.40 $10.30/MBH	$14.45 / MBH	2.5% AFUE
		Measure	Hot water boiler (< 300 MBH, 84.5% AFUE, atmospheric or forced) assumed 250 MBH	$6,187.55 $24.75/MBH		
SHW Boilers >= 300 MBH, non-condensing	DEER Measures	Baseline	Hot water boiler (300-2500 MBH; 82.0% thermal efficiency; atmospheric) assumed 1,400 MBH	$17,640.70 $12.60/MBH	$14.08 / MBH	3% TE
		Measure	Hot water boiler (300-2500 MBH, 85.0% thermal efficiency, atmospheric or forced) assumed 1,400 MBH	$37,354.94 $26.68/MBH		
		Baseline	Hot water boiler (> 2500 MBH; 82.0% thermal efficiency; atmospheric) assumed 3,000 MBH	$45,794.13 $32.71/MBH	$14.08/ MBH	3% TE
		Measure	Hot water boiler (> 2500 kBtuh, 85.0% thermal efficiency, atmospheric or forced) assumed 3,000 kBtuh	$65,508.36 $46.79/MBH		
SHW Boilers, condensing	DEER Measures	Baseline	Hot water boiler (300-2500 kBtuh; 82% thermal efficiency; atmospheric) assumed 1,400 kBtuh	$17,640.70 $12.60/MBH	$5.13/ MBH	12% TE
		Measure	Hot water boiler (300-2500 kBtuh, 94.0% thermal efficiency, condensing) assumed 1,400 kBtuh	$24,823.91 $17.73/MBH		
		Baseline	Hot water boiler (<300 kBtuh; 82% thermal; atmospheric) assumed 250 kBtuh	$2,574.40 $10.30/MBH	$30.00/ MBH	12% TE
		Measure	Hot water boiler (< 300 kBtuh, 94.0 thermal, condensing) assumed 250 kBtuh	$10,075.14 $40.30/MBH		
Steam Boilers, non-process	DEER Measures	Baseline	Steam boiler (300-2500 MBH; 77.0% thermal efficiency; atmospheric) assumed 1,400 MBH	$4,870.86 $3.48/MBH	$28.60/ MBH	8% TE
		Measure	Steam boiler (300-2500 MBH, 85.0% thermal efficiency, atmospheric or forced) assumed 1,400 MBH	$44,912.07 $32.08/MBH		
		Baseline	Steam boiler (> 2500 MBH; 77.0% thermal efficiency; atmospheric) assumed 3,000 MBH	$30,416.26 $10.14/MBH	$5.01/ MBH	3% TE
		Measure	Steam boiler (> 2500 MBH, 80.0% thermal efficiency, atmospheric or forced) assumed 3,000 MBH	$45,431.72 $15.14/MBH		
		Baseline	Steam boiler (<300 MBH; 80.0% thermal efficiency; atmospheric) assumed 250 MBH	$1,525.55 $6.10/MBH	$40.04/ MBH	2% TE
		Measure	Steam boiler (< 300 MBH, 82.0 thermal efficiency, atmospheric or forced) assumed 250 MBH	$11,535.85 $46.14/MBH		

3.6 Commercial and Industrial Refrigeration

Several in-scope commercial and industrial refrigeration measures are, in reality, more akin to "projects" rather than one-for-one replacements or add-ons and involve multiple components and highly specialized, turnkey labor. For this reason, the study team developed built-up cost estimates for these measures.

Appendix C provides a full-length report developed by the study team that provides detailed documentation and discussion of the data sources and analyses used to develop the built-up cost estimates for commercial and industrial refrigeration measures.[33] The discussion presented below is synthesized from that report.

3.6.1 Data Development and Modeling Process

The data development and cost estimation approach for each commercial and industrial refrigeration measure gave consideration to the cost elements which were most important in order to avoid details that minimally affect bottom-line measure cost. In some instances, this required more focus on the hardware costs, and in others and more nuanced understanding of installation labor or other factors. Most measures required engineering of a sample system configuration and hardware selections. For all measures, the study team interviewed equipment manufacturers and installers to refine their understanding of equipment, material, and labor cost variations for in-scope measures and to help define the "cost basis" of each measure, which for most in-scope measures meant defining prototypical project specifications.

The primary and validation data sources used were largely the same across all in-scope measures. Primary data was collected from distributor price lists, manufacturer quotes, and artificial project bids. Validation data was collected from contractor quotes, as well as previous DEER estimates. See Appendix C for measure-specific details on the data development process and the specific cost bases used for commercial and industrial refrigeration measures

3.6.2 Market Assessment Findings

In developing the measure cost estimates for commercial and industrial refrigeration measures, the study team identified a host of industry standard practice and market assessment findings relevant to measure cost estimation going forward. These include:

- According to strip curtain installers interviewed for this analysis, the lower-quality strip curtains usually last about one year under typical traffic conditions. Higher-quality strips may last 5 years or more. Manufacturers indicated that the cost is lower if the strip

[33] This report was authored by VACOM, who conducted the commercial and industrial refrigeration price data collection and analysis for this study on a turnkey basis.

curtains are purchased as part of a kit that is manufactured for a standard door size, and cost goes up if the manufacturer regards the door size as custom.

- For fan motors less than 1 HP and less than 460V, walk-in box manufacturers are offering fan duty-cycling or two-speed fan operation during the compressor off-cycle either as their standard offering or as a no-cost adder. Therefore, a measure cost estimate in the new construction context was not included in this analysis for walk-in unit coolers less than 1 HP and less than 460V.
- For floating suction pressure (FSP), programmable logic controllers (PLCs) and programmable automation controllers (PACs) are now industry-standard on industrial refrigeration control systems, and floating suction pressure logic is widely understood by controls vendors. Temperature sensors in the refrigerated spaces that are connected to the PLC or PAC are also industry-standard on new construction projects. In the new construction context, therefore, this measure is now considered baseline.
- For the industrial FSP measure cost build-up (retrofit only), the cost to procure and install a PLC or PAC and associated I/O is included in the measure cost build-up. Industrial systems, even relatively modern ones, often have no supervisory compressor sequencing or control and instead use local pressure switches or compressor micro-panels. In that instance, a supervisory controller would be required for FSP.
- Microprocessor-based compressor controls with embedded FSP logic have been ubiquitous on nearly all supermarket parallel-rack systems installed in at least the past 25 years, and the study team knows of no examples of systems in use today without them. The logic to float the suction pressure, however, is not always in use or properly commissioned. The commercial system cost build-up for this measure therefore only includes the labor to re-commission the FSP logic on the existing microprocessor controller.
- It is accepted in the industry that the federal requirements inherently limit new display cases to using LED lamps in reach-in door cases and ECM fan motors in both low-temperature reach-in door cases and medium-temperature open cases.

3.6.3 Results and Findings

As Table 3-21 below shows, the equipment cost estimates for commercial and industrial refrigeration measures are largely consistent with previous DEER estimates (where directly comparable), with a few key exceptions.[34] Again, additional detail on the specific cost bases used by the study team to develop these equipment cost estimates is provided in Appendix C, as well as additional benchmarking results from price quotes solicited from equipment installers and contractors.

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[34] The complete set of incremental cost estimates based on the measure definitions from READI v.1.0.4 “Draft Combined DEER 2011 and DEER 2014 plus IOU Ex Ante for the 2013-14 Cycle” is provided in Appendix F.

Table 3-21: Incremental Equipment Price Estimates for Commercial Refrigeration

Measure Source	Measure Description	Cost Unit	N	Cost Estimate	DEER 2008	DEER 2005	DEER 2001
DEER Measures	ECM fan motors for walk-in coolers	Per motor	4	$226.20	$230.94	$167.43	N/A
	ECM fan motors for doored display case	Per motor	6	$122.41	$230.94	$13.58	N/A
	ECM fan motors for open display case	Per motor	6	$122.41	$230.94	$13.58	N/A
	Medium temp glass doors (retrofit)	Per linear ft upright display case	3	$320.84	N/A	$514.13	$105.00
	Medium temp glass doors (new)	Per linear ft upright display case	2	$686.29	$574.87	$515.58	N/A
	Auto-closers on main cooler/freezer doors, <42" wide	Per cooler door	1	$155.67	$120.00	$322.59	N/A
Example Measure	Auto-closers on main cooler/freezer doors, >42" wide	Per cooler door	1	$917.19	$120.00	$322.59	N/A
DEER Measures	Evaporator fan control on walk-in coolers/freezers (<1 hp)	Per motor	4	$420.95	$69.69	$62.50	N/A
Example Measure	Evaporator fan control on walk-in coolers/freezers (>1 hp)	Per motor	6	$1,212	$69.69	$62.50	N/A
DEER Measures	Floating suction pressure (retrofit)	Per suction group	N/A	$-	N/A	$13.18[1]	N/A
	Floating head pressure (FHP), fixed setpoint (FSP) (air-cooled, retrofit)	Per discharge group	1	$4,008	N/A	$-	N/A
	FHP, FSP (evap-cooled, retrofit)	Per discharge group	1	$4,008	N/A	$-	N/A
	FHP, variable setpoint (VSP) (air-cooled, retrofit)	Per discharge group	1	$4,406	N/A	$10.04[1]	N/A
	FHP, VSP (evap-cooled, retrofit)	Per discharge group	1	$4,709	N/A	$8.93[1]	N/A
	FHP, VSP & variable speed (VS) (air-cooled, retrofit)	Per discharge group	1	$6,241	N/A	$294.33[1]	N/A
	FHP, VSP & VS (evap-cooled, retrofit)	Per discharge group	1	$7,390	N/A	$151.97[1]	N/A
Example Measures	Strip curtains on walk-Ins (doors <36" wide)	Per square foot	2	$8.97	$7.50	N/A	N/A
	Strip curtains on walk-Ins (doors >36" wide)	Per square foot	2	$10.75	$7.50	N/A	N/A
	LED lights in reach-in display cases	Per fixture	1	$178.05	N/A	N/A	N/A
	LED lights in open display cases	Per fixture	1	$219.17	N/A	N/A	N/A
DEER Measures	Floating suction pressure (retrofit) – industrial	Per suction group	1	$4,864	N/A	$13.18[1]	N/A
	FHP, FSP (evap-cooled, retrofit) – industrial	Per discharge group	1	$2,012	N/A	$-	N/A
	FHP, VSP (evap-cooled, retrofit) – industrial	Per discharge group	1	$2,712	N/A	$8.93[1]	N/A
	FHP, VSP & VS (evap-cooled, retrofit) - industrial	Per discharge group	1	$5,893	N/A	$151.97[1]	N/A

1 – DEER 2005 costs for these measures were expressed as per ton, rather than per discharge group or per suction group.

For ECM fan motor measures, the equipment cost estimates for walk-in cooler boxes are nearly identical to DEER 2008 estimates. However, the study team estimated much lower equipment costs for ECM fan motors in doored and open display cases (roughly half compared to the walk-in cooler boxes), whereas DEER 2008 assumed identical measure cost in all applications. This difference in equipment costs is related to significantly smaller fan motor sizes required for display case fans compared to those in walk-in cooler boxes (1/60 HP vs. 1/5 HP).

For medium-temperature glass door measures, the study team's equipment cost estimates in the retrofit case fall in between the DEER 2005 and DEER 2001 estimates. However, in the case of completely replacing existing open display cases with doored, vertical display cases, the study team's equipment cost estimates are 20-30 percent higher than previous DEER estimates and reflect the inclusion of additional piping as well as electrical connections to enable addition of ECM fan motors, anti-sweat heaters, and LED lighting (per federal requirements).

For auto-closer measures, the equipment cost estimates for "person-sized" cooler/freezer doors (i.e. <42" wide) compare well to (although slightly higher than) DEER 2008 estimates. The study team also developed separate equipment cost estimates for larger "cargo-sized" door (i.e. >42" wide) to account for the distinct difference in the door-closing technology required to automatically close larger, cargo-sized doors. Previous DEER cost estimates for this measure did not account for this technology distinction. Note that this measure applies to retrofit cases only – auto-door closers are mandated by federal standards walk-in coolers and freezers for new construction.

For evaporator fan control measures, the equipment cost estimates are significantly higher than previous DEER estimates by an order of magnitude. Previous DEER estimates appears to reflect simply wiring a timer between the compressor and fan contacts to duty cycle the fan (minimal materials costs). Interviews with installers indicated that industry standard practice for this type of intervention is to use a stand-alone fan controller product in conjunction with an ECM motor to reduce/vary fan speed as needed rather than duty-cycling the fan. The study team's equipment cost estimate therefore includes price of fan controller plus replacing the existing PSC or shaded-pole motor with an ECM motor. Note also that evaporator fan motors are typically <1 HP, but the study team also developed equipment cost estimates involving replacement of 3-phase, 460V PSC motors greater than 1 HP with corresponding ECM motors and variable-speed drives (applicable to both retrofit and new construction), for which the per-motor equipment cost is roughly 3 times higher than the <1 HP case.

For FSP and FHP measures, the equipment cost estimates are not directly comparable to previous DEER estimates since they are normalized per discharge group or suction group rather than per ton design load. Since the hardware requirements for these types of controls are mostly the same for nearly all sizes of systems, the equipment costs for these measures are mostly invariable relative to design load, and the study team therefore recommends changing the cost unit to number of suction groups (FSP) or discharge groups (FHP). Also note that the study team developed separate equipment cost estimates for commercial supermarket versus industrial refrigerated warehouse applications. Previous DEER estimates did not differentiate equipment costs for FSP and FHP measures across these two distinct contexts.

For strip curtains, the equipment cost estimates are comparable to previous DEER estimates, although slightly higher. While it is difficult to isolate exactly why the cost estimates in Table 3-21 are higher than previous DEER estimates, it should be noted that the study team's estimates are based explicitly on the assumption of using high quality (i.e. 5-year service life) strip curtains and include the cost of appropriate mounting hardware, while the DEER 2008 estimate is consistent with the prices quoted to the study team for lower quality (i.e. 1-year service life) strip curtains. Note that the study team also included separate equipment cost estimates for non-standard door sizes (i.e. larger than 36" wide), which are considered to be more expensive custom products according to manufacturers than strip curtains made for standard-size doors and bundled with mounting hardware.

For LED display case lighting, no previous DEER estimates are available to benchmark the equipment cost estimates shown in Table 3-21. However, the study team's estimates fall within the range of price quotes gathered from five installers, albeit on the higher end of the range.

3.7 Commercial Food Service and IR Film

The study team initially endeavored to collect enough price data to estimate incremental costs for commercial food service measures and IR film (for agricultural greenhouses) using a hedonic modeling approach but was forced to fall back to a matched-pair simple average approach for the reasons described further below.

3.7.1 Data Development Process

The study team collected primary data on equipment prices for commercial food service measures (fryers and convection ovens) and IR film from online distributor price lists. These price records were then backfilled with product characteristics using product-specific cut sheets. Validation benchmark data were compiled from previous DEER and IOU workpapers. It should be noted, however, that price data collection at the distributor level proved to be quite difficult for these measures for a variety of reasons, namely:

- **Limited number of qualifying products with publically available prices**. A significant number of program-eligible fryers are only made for specific franchises, e.g. Burger King. Suppliers that carry those products do not list those prices publically and refused to share them with the study team, even when guaranteed confidentiality.

Additionally, a significant number of program-eligible fryers (as currently listed by the Food Service Technology Center) are no longer produced by those manufacturers.[35]

- **Lack of non-qualified fryers being produced**. In many cases, manufacturers only produce a single line of non-qualifying fryers, typically a very basic "economy" product line. In other cases, manufacturers no longer produce non-qualifying units altogether. For example, all of the electric fryers currently produced by Pitco appear to qualify for IOU rebates in California.
- **Lack of non-qualified convection ovens being produced**. In many cases, manufacturers have discontinued all non-qualifying products and only produce qualifying units. Below we list all cases where manufacturers have discontinued non-qualifying product lines.
  - American Range only makes Energy Star/program-qualifying gas ovens
  - BKI only makes program-eligible electric and gas units (full size). Note that BKI does produce half-size electric units that are not Energy Star/program-eligible, but BKI does not make any half-size electric units that are Energy Star/program eligible (i.e. no matched pair)
  - Duke only makes program-eligible gas units
  - Hobart only makes program-eligible (full-size) gas units. Note that Hobart does produce a series of half-size gas units that are not Energy Star/program eligible, but Hobart does not make any half-size gas units that are Energy Star/program eligible.= (i.e. no matched pair)
  - Imperial only makes program-eligible electric and gas units
  - Star only makes Energy Star/program-qualified gas ovens
  - Vulcan only makes Energy Star/program-qualified gas ovens
  - Wolf only makes Energy Star/program-qualified gas ovens

In total, the study team was able to assemble 192 price data points for 28 program-eligible commercial fryers (gas and electric) but only 31 price points for 22 non-qualifying commercial fryers. Similarly, the study team was able to assemble 197 price data points for 30 program-eligible commercial convection ovens (gas and electric) but only 29 price points for 23 non-qualifying commercial convection ovens.

3.7.2 Market Assessment Findings

Perhaps the biggest factor complicating both price data collection and incremental cost analysis for commercial food service technologies is the significance of the market for used restaurant

[35] http://www.fishnick.com/saveenergy/rebates/2013_Qualifying_CFS_Products_List_Updated_Nov_14.xls

equipment. While IOU rebates target new equipment purchases (which appear to be dominated by Energy Star and/or program-eligible units), interviews conducted by the study team suggest that the industry standard practice baseline for these measures is often a refurbished unit, rather than a new, non-qualifying unit.

3.7.3 Modeling Process

For food service measures, initial attempts to isolate incremental costs due to efficiency using hedonic modeling yielded extremely poor model fits. This was related primarily to widely varying prices across suppliers for identical products. In addition, however, the key energy performance criteria specified by the FSTC (e.g. idle energy rate and cooking energy efficiency) are not typically published on product cut sheets, and the FSTC database largely does not include either FSTC or ASTM test results for non-qualifying products. In effect, this reduces the number of non-qualifying units in the analysis data set and further reduced the explanatory power of the energy efficiency variables in a regression analysis framework.

Given these dynamics within the analysis data set, the study team chose to use a matched-pair analysis, which involved assembling matched pairs of prices for qualified and non-qualified products produced by the same manufacturer and sold by the same supplier. While this approach greatly reduces the impact of supplier pricing practices on the incremental cost estimate, the tradeoff is that it severely limited the sample size for the analysis, largely due to the lack of non-qualified fryers and convection ovens currently being produced (as noted earlier).

In the case of gas and electric convection ovens, the study team was able to develop seven matched pairs of qualifying and non-qualifying products (and prices from the same supplier) – five matched pairs of full-size gas convection ovens and only two matched pairs of full-size electric convection ovens. Once the complete matched pair dataset was assembled, the study team then calculated the simple average of the price difference between each matched pair in the analysis data set. Since the matched pair dataset was limited to only full-size gas and electric convection ovens, the results should only be evaluated and applied in the context of full-size convection ovens and not be extrapolated to half-size convection ovens.

In assembling the matched pair data set and the associated product features/performance data for fryers, it became apparent that the typical metrics for fryer capacity, vat width (inches) and oil capacity (lbs), were not strict measures of the energy service produced by commercial fryers. Indeed, some high efficiency fryers are designed to lower oil capacity and oil consumption requirements for similar (if not identical) fried-food production rates. Additionally, many fryer units are designed to be combined in series, i.e. a modular approach to expanding capacity rather than strictly replacing a low-capacity unit with a high-capacity unit. In order to reduce any bias from these factors on the incremental cost analysis, the study team thus decided to normalize unit prices to production capacity (expressed as lbs of frozen French fries per hour) and conduct the matched pair calculations using the resulting "capacity-normalized" prices. From a data development standpoint, this approach required developing consistent production capacity values for each matched pair. Ideally, these production capacities would be taken from ASTM testing results rather than product cut sheets. However, as noted earlier, the FSTC product database does not include FSTC or ASTM test results for non-qualified products. In order to use internally-consistent production capacity ratings for each matched pair, therefore, the study team used the production capacities shown in the corresponding product cut sheets. While it is impossible to assess the consistency of these ratings *across* manufacturers, it is reasonable to assume that these ratings are consistent *within* the same manufacturer – providing a sufficiently meaningful apples-to-apples comparison within each matched pair. Once the complete matched pair dataset for fryers was assembled, the study team then calculated the simple average of the "capacity-normalized" price difference between each matched pair in the analysis data set.

For IR film, the baseline and high-efficiency technologies only differ due to the inclusion of two specific additives (IR reflection and anti-condensate coating) for which continuous metrics were unavailable from product cut sheets. Additionally, due to the niche nature of this product market (e.g. agricultural greenhouses), the study team was only able to collect price information for eight product families (within which individual products are only differentiated by roll size), each of which is carried by different distributors. In order to reduce the impact of supplier pricing practices on the incremental cost estimate, the study team thus chose to use a matched-pair analysis, which involved assembling matched pairs of prices for qualified and non-qualified products produced by the same manufacturer and sold by the same supplier. It should be noted that the matched pairs of IR film products were also determined by product roll size (length and width) to account for volume discounts.

3.7.4 Results and Findings

As the table notes, the previous DEER incremental equipment cost estimates are expressed on a per-unit basis, whereas the study team's estimates are normalized against production capacity (lbs/hr). In order to better benchmark the study team's estimates, the incremental equipment cost can be scaled to the "per unit" level by assuming an average production capacity, which for 14" wide fryer vats is roughly 70 lbs/hr. At this capacity, the incremental equipment cost estimate for electric fryers is $1,837/unit, which is nearly 5 times lower than the DEER 2005 estimate. However, this estimate is also roughly 2.5 times higher than the current IOU workpaper estimate, which appears to be based on a slightly larger confidential price dataset. Similarly for gas fryers, the incremental equipment cost estimate is $2,119/unit (assuming 70 lbs/hr production capacity), which is significantly lower than the DEER 2005 estimate but also significantly higher than the current IOU workpaper estimate. Table 3-22 below shows the incremental equipment price estimates for commercial food service equipment and IR film.[36]

Table 3-22: Incremental Equipment Price Estimates for Commercial Food Service and IR Film

Measure Source	Measure Description	Cost Unit	Sample N	Cost Estimate	DEER 2008	DEER 2005	DEER 2001	Other
DEER Measures	Electric fryer	Per unit production capacity (lbs/hr)	13	$27.25	N/A	$8,761.89[1]	N/A	$769.00[1]
	Gas fryer	Per unit production capacity (lbs/hr)	28	$30.28	N/A	$2,582.54[1]	N/A	$1,017.00[1]
Example measures	Electric convection oven (full size)	Per unit	10	$(590.00)	N/A	N/A	N/A	$1,007.00[1]
	Gas convection oven (full size)	Per unit	4	$(209.50)	N/A	N/A	N/A	$1,177.00[1]
	IR film	Per square foot	50	$0.020	N/A	N/A	N/A	$0.021

1 – DEER 2005 and IOU workpaper costs for these measures are expressed as per unit, rather than per unit production capacity (lbs/hr). See discussion in Section 3.7.3 for logic behind normalizing costs to production capacity going forward.

For full-size convection ovens, the estimate of incremental equipment costs are negative, whereas current IOU workpaper estimates are positive on the order of $1,000/unit (electric and gas). The study team believes this result primarily reflects the paucity of matched pairs that could be assembled for this analysis, rather than a robust analytic finding. However, it is also clear that a significant share of manufacturers have discontinued production of non-qualified convection ovens, which vastly limits the number of non-qualified new units available in the market.

For IR film, the incremental equipment cost estimates are nearly identical to the current IOU workpaper estimates. It should be noted, however, that IR film suppliers indicated that actual IR film prices can fluctuate significantly with the international price of oil, as the product is largely petroleum-based.

36 The complete set of incremental cost estimates based on the measure definitions from READI v.1.0.4 "Draft Combined DEER 2011 and DEER 2014 plus IOU Ex Ante for the 2013-14 Cycle" is provided in Appendix F.

3.8 HVAC Maintenance, SHW Distribution, Pool Covers, and Appliance Recycling

For HVAC maintenance measures, SHW distribution measures, and appliance recycling, the study team assembled primary price data from direct installation (DI) contractors who provided DI services to the IOUs over the past two program cycles (2010-2012 and 2013-2014). The study team acquired these data via formal data request to the IOUs, and the micro data provided by the IOUs is confidential. For pool covers (for hospitality applications), the study team assembled primary price data from distributor price lists. Validation benchmarks were compiled from previous DEER and IOU workpapers (HVAC maintenance), as well as RSMeans and Grainger (pipe insulation, showerheads) and Home Depot (showerheads).

3.8.1 Data Development Process

For HVAC maintenance measures (duct testing and sealing, coil cleaning, and refrigerant charging and adjustment), it is difficult if not impossible to cost-effectively develop parameters for average site conditions and specify the individual maintenance activities that field technicians may pursue, since they include a wide variety of possible interventions such as over/under charge corrections of various magnitudes, light versus deep coil cleaning, etc. Due to the ambiguity of these analytic boundaries, the study team determined that it would not be feasible to use artificial project bids, contractor quotes, or contractor telephone surveys to develop average price estimates for these measures and relied on as much “market data” that could be easily assembled (in the form of recent DI prices to the IOUs).

For appliance recycling measures, the amount of price data available is severely limited by the fact that only two contractors (JACO and ARCA) handle the IOUs’ appliance recycling programs statewide. In this sense, there is no other contractor “population” from which to acquire price data, and the resulting price data set is extremely small. Similarly for pool covers (in hospitality applications), discussions with manufacturers indicated that there are only three manufacturers of such products in the U.S., all of whom distribute their products directly to final customers. As such, the resulting price data set for this measure is also very limited.

3.8.2 Market Assessment Findings

There were no significant market assessment findings that resulted from the study team’s data development efforts other than the very limited nature of the appliance recycling and pool cover markets, as noted previously.

3.8.3 Modeling Process

Given these limited sample sizes for these measures, it was not appropriate to estimate average equipment prices using hedonic price modeling. For these measures, the study team used unweighted simple averages. It should be noted that some labor and materials costs were not disaggregated in DI price data provided by the IOUs. This served to further reduce sample sizes for some measures. Wherever possible, the study team produced alternative cost estimates based on aggregate data, i.e. total installed cost only, with no separation of labor and materials costs, as an additional benchmark.

3.8.4 Results and Findings

Table 3-23 below shows the study team's incremental equipment price estimates for HVAC maintenance measures, SHW distribution measures, pool covers, and appliance recycling. As the table shows, the estimates are largely consistent with previous DEER estimates, with one key exception as described below. Note that no benchmarks were readily available for coil cleaning, economizer repair, or pool covers.

Table 3-23: Incremental Equipment Price Estimates for HVAC Maintenance, SHW Distribution, Pool Covers, and Appliance Recycling

Measure Source	Measure Description	Cost Unit	Sample N	Cost Estimate	DEER 2008	DEER 2005	DEER 2001	Other
DEER Measures	Duct Testing and Sealing	Per dwelling	2	$71.45	$55.75	$16.67	N/A	N/A
	Refrigerant Charging and Adjustment	Per ton cooling served	10	$9.92	$11.55	$14.11	N/A	N/A
Example Measures	Evaporator Coil Cleaning (nonres)	Per ton cooling served	5	$7.98	N/A	$-	N/A	N/A
	Condenser Coil Cleaning (nonres)	Per ton cooling served	6	$6.73	N/A	N/A	N/A	N/A
	Economizer repair	Per ton cooling served	11	$19.64	$-	$-	N/A	N/A
DEER Measure	Pipe Insulation (SHW)	Per linear foot	4	$8.98	$0.88	$0.37	N/A	$7.61[1]
Example Measure	Pipe Insulation (steam)	Per linear foot	2	$12.18	N/A	N/A	N/A	$1.42[1]
DEER Measure	Lowflow Showerheads	Per showerhead	9	$18.50	$29.22	$22.95	$9.23	$29.63[2]
Example Measure	Pool covers (nonres)	Per square foot	9	$2.20	N/A	N/A	N/A	N/A
DEER Measure	Ref/freezer Recycling (res, 1 unit)	Per unit	2	$78.00	$77.13	$97.75	N/A	N/A
Example Measures	Ref/freezer Recycling (res, 2+ units)	Per unit	2	$50.00	$77.13	$97.75	N/A	N/A
	Ref/freezer Recycling (nonres, 1 unit)	Per unit	2	$78.00	$77.13	$97.75	N/A	N/A
	Ref/freezer Recycling (nonres, 2+ units)	Per unit	16	$46.56	$77.13	$97.75	N/A	N/A

1 – RSMeans 2013 (installation of closed cell foam insulation on SHW pipes, averaged across estimates for 0.5" to 1.5" pipes).

2 – Simple average of the 3 "top seller" qualifying units from Grainger and 10 "top seller" qualifying units from Home Depot. Note this average reflects full retail prices, rather than DI contractor bulk prices to the IOUs.

For SHW pipe insulation, the equipment cost estimate shown in Table 3-23 is an order of magnitude higher than previous DEER estimates ($9/ft compared to >$1/ft). However, this estimate (based on DI prices) is consistent with both RSMeans and the average price of a sample of "top seller" qualifying products from Grainger (assuming 40 percent contractor markup). For steam pipe insulation, it should also be noted that average DI prices for this measure appear to include installation labor, given the RSMeans benchmark for average materials cost.[37]

Note that for appliance recycling, both the study team's cost estimates and the previous DEER estimates do not separate materials costs from labor costs. The comparisons shown in Table 3-23 for these measures reflect total costs and should not be interpreted as strictly "equipment prices".

3.9 Network Power Management Software

Estimating the average installed price of network power management software presents several significant challenges. First and foremost, there are many freeware/public domain software packages readily available that enable central administration of the sleep and on-off schedules for a network of client PCs, including the EZ GPO software package developed by Energy Star.[38] Since the current IOU workpapers for this measure are focused on commercial products, the study team attempted to collect and analyze average prices for commercial network power management software solutions. To do this, the study team focused on collecting prices for the commercial solutions listed on the Energy Star website.[39]

3.9.1 Data Development Process

In collecting and analyzing prices for that list of commercial software products, the study team faced a host of significant challenges. First, most software prices were not publically listed by developers. The study team was thus required to approach developers directly and solicit price quotes. Several developers were not willing share their prices and several others did not return requests for prices.

Second, per-client prices for software licenses varied widely with volume. From our discussions with developers and their respective sales staff, final prices for these types of software products (as with many enterprise software products) appear highly subject to negotiation, both on initial license prices and renewal/maintenance terms. Thus the price quotes provided to the study team should be understood and interpreted in that context.

3.9.2 Market Assessment Findings

As stated previously, both commercial software and freeware are available that enable central administration of the sleep and on-off schedules for a network of client PCs.

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37 The RSMeans estimate of average total installed cost for this measure (labor plus materials) is $9.98/ft.

38 http://www.energystar.gov/index.cfm?c=power_mgt.pr_pm_ez_gpo

39 http://www.energystar.gov/index.cfm?c=power_mgt.pr_power_mgt_comm_packages

3.9.3 Modeling Process

The study team encountered a number of significant issues that affect the estimation of average price for commercial network power management software. First, it was very difficult to cleanly delineate differences in power management strategies, their relative effectiveness, and their impact on price, e.g. direct implementation of sleep settings and on-off schedules compared to client-specific energy consumption dashboards and learning algorithms. Detailed information on product-specific functionality and power management strategies were largely limited to interpreting product marketing literature. It was therefore difficult if not impossible to verify claims made by developers (either over the phone or in their product literature) without acquiring, testing, and/or examining the source code of each product, which was well beyond the scope and priorities of this study. Second, higher-priced products often bundle features not related to power management functionality. This dynamic further complicates the basic task of delineating between the impacts of increased power management functionality versus other functionality on software prices.

In total, the study team was able to assemble per-client license prices for 11 of the commercial products listed by Energy Star. The team excluded two products from the analysis set whose installed price exceeded $100/client PC due to their respective claims to be a “total IT solution”. For these two products, the overall functionality of the software very clearly go well beyond solely power management, including features such as computer imaging, patch management, MDM security, and bring-your-own-device (BYOD) policy automation. Using the prices collected for the 9 other commercial products, the study team then normalized the quoted prices against the maximum allowed number of client PCs associated with each respective product license and calculated the simple average per-client price.

3.9.4 Results and Findings

The study team’s cost estimate for network power management software benchmarks well compared to the current IOU workpaper estimate, shown in the rightmost column of Table 3-24 below. However, given the analytic challenges and issued described above (namely feature bundling, one-off price setting, and availability of freeware), it is difficult to judge the overall representativeness of this estimate in the context of the current market in California.

Table 3-24: Incremental Equipment Price Estimates for Network Power Management Software

Measure Source	Measure Description	Cost Unit	Sample N	Cost Estimate	DEER 2008	DEER 2005	DEER 2001	Other
Workpaper Measure	Network Power Management Software	Per client PC	9	$17.07	N/A	N/A	N/A	$20.00

4

Labor and Non-Equipment Installation Costs – Final Data Sources and Results

This section presents the final data sources and ex ante estimates of non-equipment installation costs for all in-scope measures, where required to calculate incremental measure costs. This section also provides additional detail and narratives on the technology-specific installation cost estimation issues encountered by the study team and their respective resolutions. The complete set of recommended installation cost values is provided in Appendix F.

In general, non-equipment installation costs are needed to estimate the incremental costs of all add-on and early replacement (ER) measures. For add-on measures such as variable-frequency drives or hot water pipe insulation, the incremental measure cost is equal to the full, installed measure cost, which by definition includes non-equipment installation costs. For ER measures such linear fluorescent lamp replacements, incremental costs are calculated on a dual baseline basis. In this case, incremental cost is equal to full, installed measure cost during the remaining useful life (RUL) of the inefficient equipment being replaced, after which it is equal to the incremental cost between the measure and the code-compliant baseline equipment.

Calculating incremental costs for replace-on-burnout (ROB) measures typically does not require estimating non-equipment installation costs, particularly when the equipment in question is simply a higher-efficiency version of the code-compliant baseline equipment (e.g. high SEER split-system DX). In these cases, the non-equipment installation costs are ostensibly identical and thus cancel in the incremental cost calculation. An important exception, however, is when the high-efficiency technology is not simply a higher-efficiency version of the same technology, such as when a tankless water heater is chosen to replace a storage tank water heater that has ceased to function. In this case, which we refer to as a "cross-technology baseline", the non-equipment 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 installation costs thus becomes critical to correctly estimating incremental measure costs.

For this study, the study team estimated non-equipment installation costs for all in-scope add-on measures, ER measures, and ROB measures that involve cross-technology baselines.[1]

[1] The study team did not attempt to develop installation costs for pool covers and network power management

Additionally, the study team estimated non-equipment installation costs for a subset of measures that are treated strictly as ROB under deemed incentive programs but are often claimed as ER under calculated incentive programs.[2] These measures are primarily non-residential HVAC equipment such as chillers, boilers, packaged DX/HPs, and split-system DX/HPs.

In the subsections that follow, installation cost estimates are shown at the individual technology or measure level, but the presentation and discussion of results are grouped by technologies and measures with common data sources and/or data analysis methods using the general structure:

- Summary of the data development approach
- Summary of all final data sources used
- Summary of results and benchmarking findings

It is important to note that the summaries and discussions below were designed to be supplementary to the discussions of the general data collection, data development, and data analysis methods and approaches presented previously in Section 2.

It is also important to note that in order to reduce systematic bias and increase internal consistency, the study team used labor rates ($/hr) taken from RSMeans, except in cases where labor rates were provided in artificial project bids. As such, the study team's data development efforts primarily focused on estimating installation labor hours and other non-labor, non-equipment installation costs (e.g. crane rental, permits, piping) rather than collecting data to develop weighted average labor rates. The study team did, however, transform the RSMeans labor rates from national averages (as published) to California statewide averages. To do this, the study team used the RSMeans city cost indices for each of 16 California climate zones in combination with 2010-2012 program participation data (at the climate-zone level) to develop a statewide index weighted by location-specific program participation (a proxy for overall market activity).[3] The city-specific cost indices, climate-zone weights developed from program tracking data, and resulting statewide average cost index are provided in Appendix G.

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software, both of which are add-on measures. For the former, discussions with equipment vendors indicated that this equipment is always installed by the customer themselves. For the latter, given the lack of detailed information on product-specific functionality, power management strategies, and installation requirements, the study team did not attempt to develop installation costs for this measure.

2 Conceivably, food service measures could be claimed as ER under calculated incentive programs. However, the team's discussions with equipment vendors indicated that nearly all new fryers and convection ovens (electric and gas) are designed to be plug-and-play equipment and customers rarely request third-party assistance for installation. The study team therefore did not attempt to develop installation cost estimates for those measures.

3 Separate statewide, participation-weighted indices were developed for lighting measures and HVAC measures. For the latter, the study team used the RSMeans City Cost Indexes for Fire Suppression, Plumbing, and HVAC in combination with climate-zone specific HVAC project claims data from the 2010-2012 program cycle. For the former, the team used the RSMeans City Cost Indexes for Electrical, Communications, and Utilities in

4.1 Split-System and Packaged DX and HP

4.1.1 Data Development Process

To develop estimates of labor and non-equipment installation costs for split and packaged DX and HP systems, the study team primarily used the results of a large sample telephone survey of currently licensed HVAC contractors in California. This survey, known as the Joint HVAC Contractor Survey, was conducted jointly with two other work orders – WO24 (Commercial Market Share Tracking Study) and WO32 (Residential and Small Commercial HVAC Impact Evaluation). The sample frame for the survey was originally developed by EMI on behalf of the IOUs as part of the 2012 California HVAC Contractor and Technician Behavior Study.[4] This sample frame was based on the complete list of contractors currently licensed by the State of California to install and maintain HVAC systems (known as the C20 license), which EMI acquired from the Contractor State License Board. The survey instrument covered three primary areas: 1) installation labor requirements for new/replacement split and packaged units (WO17), 2) market shares of high efficiency units (WO24), and 3) maintenance practices for split and packaged units (WO32). Itron's Computer Aided Telephone Interview (CATI) survey center implemented the survey, and a total of 123 HVAC contractors responded. Complete details of this survey effort are provided in Appendix D, including a memorandum describing development of the sample frame, the final survey instrument, the final survey disposition, and the expansion weights applied to the survey results.

The study team designed the battery of survey questions focused on installation labor requirements with three specific objectives in mind: 1) to strategically limit the scope of the survey questions to the technologies and systems that represented the largest portion of new HVAC installations in California, 2) to explicitly frame the site conditions and project scopes to reduce variability in self-reported estimates, and 3) to solicit estimates of other key non-labor, non-equipment installation costs. The resulting battery of questions focused on the replacement of old, existing split and packaged DX units with new units. Separate questions were asked regarding the crane rental costs, disposal costs, and the labor requirements (in man-hours) for removal, installation, and testing. The study team pre-tested the survey questions with a small sample of HVAC contractors to ensure clarity and assess the consistency of responses.

The questions related to labor requirements were framed in two different scenarios, as summarized in Table 4-1 below.

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combination with climate-zone specific lighting project claims data from the 2010-2012 program cycle.

4 See: http://www.calmac.org/publications/CA_HVAC_Behavior_Study_FinalReport_2012Sept14_FINAL.pdf

Table 4-1: Installation Scenarios Used in HVAC Contractor Survey

Technology	Installation Scenario	Other Framing Assumptions
Split-system DX/HP	Replacing 5-ton unit located on low-rise, flat-roofed, commercial building	Includes time associated with pulling refrigerant out, disconnecting electrical and controls, disconnecting the unit from the curb, removal of the unit by crane, moving new unit into place with a crane, attaching refrigerant piping, connecting electrical and gas as necessary, connecting ductwork, testing, and commissioning installed unit, taking the old unit to the recycler
Small Pkg DX/HP	Replacing 5-ton unit located on low-rise, flat-roofed, commercial building	
Large Pkg DX	Replacing 40-ton unit located on low-rise, flat-roofed, commercial building	

The survey questions also provided a host of additional detailed framing assumptions, including the following:

- No new curb is required and no new screen is required to conceal the unit. However, the labor estimate should include preparing the existing curb and installing new curb gaskets
- Testing and commissioning includes the time required for checking belt alignment, starting compressors and making sure pressure is correct, checking combustion efficiency (in the case of gas units), checking for air leaks in the ductwork, making sure amperage is in the acceptable range, and balancing air flow
- Disposal costs include only the fee charged by the recycler
- Crane rental costs include only the cost of rental. The labor hours required for operating the crane should be included in installation and removal labor hours

Note that while the HVAC contractor survey questions were specific to DX units, discussions with HVAC contractors and engineers indicated that installation costs for split DX and HP systems of the same capacity do not differ significantly. Similarly, HVAC contractors and engineers indicated that the installation costs for packaged DX and HP systems of the same capacity do not differ significantly. However, as discussed previously in Section 3.5.2, because manufacturers no longer produce packaged HP units larger than 20 tons, the contractor responses for 40-ton packaged DX installations cannot be reasonably applied to 20-ton packaged HP installations. To estimate labor requirements and non-labor installation costs for large packaged HPs, the study team used data assembled from a small sample of artificial project bids.

Also note that because the contractor survey was specific to a commercial installation location on a low-rise, flat-roofed commercial building, the study team found that the labor hours and miscellaneous installation costs reported by the contractors were unrealistically high and included costs not applicable to residential split DX and HP systems (e.g. removal and placement using cranes). Residential installation conditions are typically more accessible (e.g. ground-mounted outdoor condenser units) and therefore less time-consuming than commercial installations. In the absence of additional primary data specific to residential split system installations, the study team adopted installation labor estimates developed and published by the U.S. Department of Energy (USDOE) in the Technical Support Document (TSD) for the most recent standards rulemaking for residential central air conditioner, heat pump, and furnace.[5] Specifically, the national average total installation cost from the TSD was weighted to the California statewide average using the RSMeans regional multipliers (provided in the TSD). This cost was then divided by the average hourly labor rate from the artificial bids to arrive at average labor hours per installation. Because split system DX and HPs are only available in a relatively small capacity range, the installation costs are assumed to be fixed across that range (i.e. do not scale with capacity – see additional discussion below).

To validate the labor hours and labor rates developed from the HVAC contractor survey and the artificial project bids, the study team benchmarked each set of estimates against labor hours and labor rates from RSMeans, DEER 2008, and artificial bids (where not used as primary data). The final data sources used to develop and validate our estimates of installation labor hours and rates for split and packaged DX and HP units are shown in Table 4-2 below. Note that in addition to developing installation labor hours and rates, the study team also developed estimates for miscellaneous non-equipment installation costs that were not captured in the contractor survey, including miscellaneous electrical and plumbing materials, miscellaneous sheet metal, and costs associated with engineering and survey, project management, permits, insurance, bond, contingency, and warranty. Estimates for these costs were developed from the artificial bids.

Table 4-2: Final Data Sources for Installation Costs – Split-System and Packaged DX and HP

Technology	Primary Data Source		Validation Data Source	
	Labor Hours	Labor Rates	Labor Hours	Labor Rates
Split-system HP	Contractor survey, USDOE TSD	Artificial bids	RSMeans, Artificial bids, DEER 2008	RSMeans, DEER 2008
Split-system DX				
Small Pkg HP	Contractor survey	RSMeans	RSMeans	None
Large Pkg HP	Artificial bids	Artificial bids		RSMeans
Small Pkg DX	Contractor survey	RSMeans	RSMeans, DEER 2008	DEER 2008
Large Pkg DX		Artificial bids	RSMeans, Artificial bids, DEER 2008	RSMeans, DEER 2008

4.1.2 Results and Findings

Table 4-3 presents the study team's estimates of non-equipment installation costs for split and packaged DX and HP units. All labor hour estimates are expressed per ton of cooling capacity and include hours associated with removal of the old unit, installation of the new unit, and

5 http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012

testing/commissioning. Labor rates are bare labor rates, i.e. without markups.[6] The total average markup for these installation projects is shown separately and reflects the average markup across the artificial bids. Finally, total non-equipment installation cost is presented in dollars per ton.

Table 4-3: Installation Cost Estimates for Split-System and Packaged DX and HP

Technology	Capacity Unit	Labor Hours (hrs/ unit)	Labor Rate ($/hr)	Misc. Costs per Unit ($/unit)	Misc. Fixed Costs ($/ project)	Mark-up (%)	Total Non-equipment Installation Cost ($/unit)
Res Split-System HP	Unit	8.00	$71.30	-	-	28%	$727.62
Nonres Split-System HP	Unit	31.35	$71.30	$1790.23	$598.38	28%	$5,132.70
Res Split-system DX	Unit	7.26	$71.64	-	-	28%	$662.77
Nonres Split-System DX	Unit	31.35	$71.64	$2,245.00	$598.38	28%	$5,801.25
Small Pkg HP	Ton	6.27	$70.78	$338.71	$598.38	28%	$997.74
Large Pkg HP	Ton	4.3	$70.78	$326.97	$598.38	28%	$804.95
Small Pkg DX	Ton	6.27	$70.69	$261.71	$598.38	28%	$898.87
Large Pkg DX	Ton	1.52	$70.69	$251.44	$598.38	28%	$457.87

Note that Table 4-3 presents two sets of miscellaneous installation costs – those that scale with the size of the installed unit (e.g. piping, sheet metal, contingency, and warranty) and those that are fixed (e.g. crane rental, controls, and permits). The total non-equipment installation costs shown in the right-most column of Table 4-3 represent the sum of the marked-up labor costs and the marked-up, scalable miscellaneous costs but exclude miscellaneous fixed costs. To estimate total installation costs for a specific capacity unit, one would multiply the values in the right-most column of Table 4-3 by the capacity of the unit in question and then add the miscellaneous fixed costs.

The subsections below present and discuss how the estimates in Table 4-3 benchmark to corresponding estimates from RSMeans, DEER 2008, and the artificial bids. Note that where RSMeans were used to benchmark the study team's estimates of installation labor hours, there was often a wide range of capacities associated with a given technology. In these cases, an average value was calculated and presented for benchmarking purposes.

[6] Note that where labor rates were developed from artificial bids, the study team re-weighted the original estimates (from Bay Area contractors) to California statewide averages using the same participation-weighted indices used to the aggregate the location-specific RSMeans city cost indices (see tables in Appendix G).

Split-System HPs

The study team's estimated installation labor hours for residential units (8 hr) from the USDOE TSD benchmarks low compared to DEER 2008 for a three-ton unit (18 hrs). However, DEER 2008 assumes installation labor hours scale linearly with capacity. From discussions with HVAC contractors and engineers, total installation labor hours follow a "tiered" relationship relative to unit size, i.e. relatively fixed within certain ranges of unit capacity. According to these contractors and engineers, split-system HPs all fall within the same "tier" (e.g. 1-5 tons) and require approximately the same number of hours for installation. Similarly, the USDOE TSD provides a single, static cost for installation labor for these systems, irrespective of capacity. For non-residential units, the contractor survey average labor hours estimate of 31.35 hours benchmarks well to both RSMeans (30.48 hrs) and the average of the artificial bids (38 hours).

Split-System DX

Similar to split system HPs, the estimated installation labor hours for residential units (7.26 hours) from the USDOE TSD benchmarks low compared to DEER 2008 for a three-ton unit (18 hours). Again, the study team believes that this is a result of the false assumption that installation costs scale linearly with capacity. The USDOE TSD estimate benchmarks more closely to the RSMeans estimate of 10.9 hours for a three-ton unit. For non-residential units, the contractor survey average installation time estimate of 31.35 hours is considerably lower than the average from the artificial bids (50.5 hours). The contractor survey had a much larger sample size and much less variability than the artificial bids, however, and the study team has a high level of confidence in the contractor survey figures.

Packaged HP

The study team's estimated installation labor hours for small packaged HP units based on the contractor survey (6.27/ton) are slightly higher than the corresponding RSMeans estimate (4.27/ton). The average labor rate ($70.78/hr) – based on the average from the artificial bids – is also somewhat higher than the RSMeans labor rate ($59.04/hr). For large packaged HP, the study team's labor hours estimate is based on the average from two different artificial bid installation scenarios (ground and roof) for a 7.5-ton packaged HP, for which the difference between the two scenarios was negligible (2 percent). The study team's average labor hours per ton estimate (4.3 hr/ton) is slightly higher than the corresponding RSMeans estimate (3.19 hr/ton), as is the labor rate ($70.78/hr vs. $59.58/hr).

Packaged DX

The study team's estimated installation labor hours for small packaged DX units based on the contractor survey (6.27 hr/ton) compare well to both RSMeans (5.33 hr/ton) and DEER 2008 (5.27 hr/ton). The average labor rate ($70.69/hr) – based on the artificial bids – are somewhat higher than both RSMeans and DEER 2008 ($59.04/hr and $67.88/hr, respectively). For large packaged DX units, the study team's estimated installation labor hours (1.52 hr/ton) benchmark also compare well to RSMeans (2.72-3.25 hr/ton), artificial bids (1.11-1.96 hr/ton) and DEER 2008 (2.23-4.55 hr/ton). As will small packaged units, the estimated average labor rates ($70.69/hr) – based on the artificial bids – are slightly higher than the corresponding estimates from RSMeans ($59.04-$61.23/hr) and DEER 2008 ($67.88/hr).

It is important to note that the point estimates for small packed DX and large packaged DX from the contractor survey (5-ton and 40-ton, respectively) may not be appropriate for all capacities due to the wide range in tonnage. This is particularly apparent at the low end of the range for large packaged DX. Because this measure group includes units as small as 6-tons, applying the point estimate of 1.52 hr/ton (based on the survey results for 40-ton units) results in substantially fewer installation hours for a 6-ton unit than a 5-ton unit. The study team, therefore, recommends using a linear approximation of labor hours for units with capacities that vary substantially from 5- and 40-tons. As discussed further in Chapter 5, the evaluation team believes that the relationship between capacity and installation labor hours is not strictly linear for large capital equipment but is, rather, a step function based on specific capacity ranges. Because sufficient data were not available to fully develop this step function, the study team recommends using the straight line approximation between the two point estimates from the contractor survey (hr = 0.845[tons] + 27.129). While a linear function based on two points is far from ideal, the study team believes the function provides realistic estimates for most capacities. This claim is validated by the fact that a very similar function was developed from five artificial bid data points for 20- to 70-ton units (hr = 0.56[tons] + 38.8). The slopes of these two lines are quite similar, with a slight flattening at the higher capacities, as would be expected.

Other Non-equipment Installation Costs

For packaged DX and HP systems, there are several major non-equipment installation costs that have not previously been quantified in DEER. First, there are non-equipment materials necessary for installation such as miscellaneous piping, wiring, and sheet metal. Second, there are costs associated with engineering/survey, project management, permits, insurance, bond, contingency, and warranty. Finally, these are heavy and bulky pieces of equipment that require a forklift or crane and rigging to move into place.

In this analysis, it is assumed that the miscellaneous materials and the soft costs (engineering, project management, etc.) scale linearly with capacity. The subcontractors participating in this study indicated that while the crane and rigging costs do vary by capacity and installation location, there is no clear way to scale these costs directly to capacity. Due to the strategically precise nature of the installation cost questions in the HVAC contractor survey, it was not practical to use that survey to gather information on how costs of crane rental vary with capacity or installation location. In this sense, the estimates of both fixed and scalable miscellaneous installation costs shown in Table 4-3 should be interpreted as average, prototypical values. Note, however, that data from the artificial bids suggest crane rental for very large packaged DX units may be substantially higher, e.g. $600-$4,500 depending on the scenario.

4.2 Linear Fluorescent Lighting and Occupancy Sensors

4.2.1 Data Development Process

To develop estimates of labor and non-equipment installation costs for linear fluorescent lighting measures and occupancy sensors, the study team primarily used the results of a large sample telephone survey of nonresidential lighting contractors in California. This survey, known as the Joint Lighting Contractor Survey, was conducted jointly with three other work orders – WO24 (Commercial Market Share Tracking Study); WO29 (Nonresidential Downstream Lighting Impact Evaluation); and WO54 (Market Effects). The sample frame was developed from InfoUSA business data covering multiple NAICS codes that include electrical contractors and suppliers. The survey instrument covered three primary areas: 1) installation labor requirements for linear fluorescent lighting and occupancy sensors (WO17), 2) market shares of high efficiency linear fluorescent lamps (WO24), and 3) program influence on lighting equipment purchases and contractor recommendations (WO29), 4) impact of the T12 phaseout on lighting equipment purchases and contractor recommendations (WO29), and 5) market trends, market shares, and customer perceptions of LED lighting products (WO54). Itron's Computer Aided Telephone Interview (CATI) survey center implemented the survey, and a total of 95 nonresidential lighting contractors responded. Complete details of this survey effort are provided in Appendix E, including a memorandum describing development of the sample frame, the final survey instrument, the final survey disposition, and the expansion weights applied to the survey results.

The study team designed the battery of survey questions focused on installation labor requirements with three specific objectives in mind: 1) to strategically limit the scope of the survey questions to the technologies and systems that represented the largest portion of nonresidential lighting retrofits in California, 2) to explicitly frame the site conditions and project scopes to reduce variability in self-reported estimates, and 3) to solicit estimates of other key non-labor, non-equipment installation costs. The resulting battery of questions focused on linear fluorescent lamp change-outs, ballast replacements, fixture replacements, delamping, and installation of occupancy sensors. The study team pre-tested the survey questions with a small sample of lighting contractors to ensure clarity and assess the consistency of responses.

The questions related to installation labor requirements were framed in two or three different scenarios (depending on the technology), as summarized in Table 4-4 below.

Table 4-4: Installation Scenarios Used in Lighting Contractor Survey

Technology	Installation Scenario 1	Installation Scenario 2	Installation Scenario 3	Other Framing Assumptions
Linear Fluorescent T8/T5 Lamps	Replacing two lamps recessed in T-bar ceiling accessible with a ladder	Replacing two lamps in high-bay ceiling accessible with a lift	N/A	Includes removal of existing lamp, installation of new lamps, and commissioning
Linear Fluorescent Ballasts	Replacing one ballast recessed in T-bar ceiling accessible with a ladder	Replacing one ballast in high-bay ceiling accessible with a ladder	N/A	Includes removal of existing ballast, wiring and installation of new ballast, and commissioning
Linear Fluorescent Fixtures	Replacing a 4' T12 fixture with 4' T8 or T5 fixture, recessed in T-bar ceiling accessible with a ladder	Replacing a 4' T12 fixture with 4' T8 or T5 fixture, surface counted on T-bar ceiling accessible with a ladder	Replacing a HID fixture with a T5 fixture in high-bay ceiling accessible with a lift	Includes removal of existing fixture (lamps, ballast, and luminaire), wiring and installation of new fixture, and commissioning
Occupancy Sensors	Installation of wall-mounted unit	Installation of ceiling-mounted unit	Installation of fixture-integrated unit in existing fixtures	Includes wiring, installation, programming, and commissioning*

* Also includes time required for disassembling and re-assembling fixture in Scenario 3.

The lighting contractor survey also included one question on disposal costs related to linear fluorescent lamps, ballasts, and fixtures. The question asked how long it takes to prepare removed linear fluorescent lamps/ballasts/fixtures for disposal in terms of man-hours per 100 lamps/fixtures/ballasts. It included the time required for collecting items for disposal, managing broken items, packaging, and arranging for pick-up. The estimate did not include the time it takes for the disposal companies to pick up and dispose of the equipment or the physical disposal fee.

To validate the labor hours and labor rates developed from the lighting contractor survey, the study team benchmarked each set of estimates against labor hours and labor rates from RSMeans, DEER 2008, and artificial project bids. The final data sources used to develop and validate our estimates of installation labor hours and rates for linear fluorescent lighting and occupancy sensors are shown in Table 4-5 below. Note that in addition to developing installation labor hours and rates, the study team also developed estimates for miscellaneous non-equipment installation costs including disposal preparation labor, disposal fees, and lift rental. The estimates for the latter two miscellaneous costs were developed from the artificial bids.

Table 4-5: Final Data Sources for Installation Costs – Linear Fluorescent Lighting and Occupancy Sensors

Technology	Primary Data Source		Validation Data Source	
	Labor Hours	**Labor Rates**	**Labor Hours**	**Labor Rates**
Linear Fluorescent T8/T5 (All lengths)	Contractor survey	RSMeans	RSMeans	None
Linear Fluorescent Ballasts (All types)			None	
General Service Linear Fluorescent Fixtures (All types)		Artificial bids	Artificial bids, RSMeans, DEER 2008	RSMeans, DEER 2008
High Bay Linear Fluorescent Fixtures			RSMeans, Artificial bids	RSMeans
Occupancy Sensors			RSMeans, DEER 2008	

4.2.2 Results and Findings

Table 4-6 presents the study team's estimates of non-equipment installation costs for fluorescent lighting and occupancy sensors. All installation labor hour estimates are expressed per fixture or per sensor, as appropriate. Note that in previous versions of DEER, installation cost estimates for linear fluorescent lamp and ballast measures were expressed on a per-lamp or per-ballast basis. However, in our survey pre-test, lighting contractors indicated that the installation hours required for lamp replacements and ballast replacements are only weakly related to the number of lamps or ballasts per fixture and that industry standard practice is to estimate installation costs based on the number of fixtures within the project scope and not the number of lamps or ballasts.

Labor rates shown in Table 4-6 are bare labor rates, i.e. without markups.[7] The total average markup for these installation projects is shown separately and reflects the average labor and materials markup for these measures in RSMeans.[8] Finally, total non-equipment installation cost presented in Table 4-6 is expressed in dollars per fixture or sensor as appropriate.

[7] Note that where labor rates were developed from artificial bids, the study team re-weighted the original estimates (from Bay Area contractors) to California statewide averages using the same participation-weighted indices used to the aggregate the location-specific RSMeans city cost indices (see tables in Appendix G).

[8] Note that RSMeans does not provide labor, materials, or markup estimates for ballast-only retrofits. In this case, the study team used assumed a 25 percent average markup for labor and materials, which is consistent with the RSMeans markups for lamp-only retrofits.

Table 4-6: Installation Cost Estimates for Linear Fluorescent Lighting and Occupancy Sensors

Technology	Capacity Unit	Labor Hours (hrs/ unit)	Labor Rate ($/hr)	Misc. Costs per Unit ($/unit)	Markup (%)	Total Non-equipment Installation Cost ($/unit)
Linear Fluorescent T8/T5 lamps – ladder accessible	Fixture	0.58	$58.27	$6.61	24%	$49.86
Linear Fluorescent T8/T5 lamps – high bay, lift accessible	Fixture	0.89	$58.27	$6.61 + $14.63	24%	$90.45
Linear Fluorescent Ballasts – recessed, ladder accessible	Fixture	0.81	$58.27	$6.61	25%	$67.15
Linear Fluorescent Ballasts – high bay, lift accessible	Fixture	1.28	$58.27	$6.61 + $14.63	25%	$119.81
Linear Fluorescent Fixtures – T12 to T5/8, recessed and ladder accessible	Fixture	1.26	$57.89	$6.56 + $11.95	34%	$122.25
Linear Fluorescent Fixtures – T12 to T5/8, suspended or surface mounted and ladder accessible	Fixture	1.15	$56.31	$6.38 + $18.14	34%	$119.59
HID to T5 Fixtures – high bay, lift accessible	Fixture	2.02	$50.20	$5.69 + $14.63 + $17.99	34%	$187.14
Occupancy Sensors – wall mounted	Sensor	1.19	$56.55	$5.34	26%	$91.85
Occupancy Sensors – ceiling mounted	Sensor	1.51	$56.55	$13.12	26%	$124.11
Occupancy Sensors – fixture integrated	Sensor	1.14	$56.55	$7.58	26%	$90.46

Linear Fluorescent T8/T5 Lamps

The study team's estimated installation labor hours for retrofitting existing fixtures with T8/T5 lamps (0.58 and 0.89 hours/fixture for ladder and lift accessible fixtures, respectively) are high compared to the benchmarks from RSMeans (0.08-0.1 hours/lamp or ~4.8-6 minutes/lamp). Importantly, RSMeans does not specify the exact installation conditions or activities reflected in their estimates. Nonetheless, these estimates appear to be unreasonably low, especially for fixtures requiring a lift to access them. The contractor survey was very precise about the activities included in the lamp replacement project, and the variation across respondents was low (10-14 percent). In this respect, the study team believes the self-reported labor hours from the contractor survey to be a more realistic estimate.

The miscellaneous installation costs for this measure are the labor required to prepare 100 removed lamps for disposal (0.11 hr/lamp) multiplied by the labor rate shown in Table 4-6. This is based on the contractor-reported estimate of the labor hours required to prepare 100 lamps, ballasts, and fixtures for disposal. However, the evaluation team had no way of disaggregating these estimates to reflect only preparation of removed linear fluorescent lamps. In this respect, the study team believes that the miscellaneous costs shown in Table 4-6 are likely to be biased high for lamp-only retrofit projects. The second set of miscellaneous costs ($14.63/fixture) is the rental cost of a lift from the artificial bids for high bay applications (based on an installation of 50 fixtures). Some facilities may have their own lift so this cost may not apply in all situations. Finally, while disposal labor hours are accounted for in the labor costs, there would also be a physical disposal fee for the lamps themselves. As described below, physical disposal costs for entire fixtures were obtained from the joint lighting contractor survey, but lamp-only disposal fees were not. On-line sources put the per lamp disposal cost between $0.35-$1.00/lamp.[9]

Linear Fluorescent Ballasts

For linear fluorescent ballast retrofits, benchmark data for installation labor hours or costs were not readily available from DEER 2008, RSMeans, or the artificial bids. The miscellaneous costs shown in Table 4-6 reflect the labor required to prepare 100 units for disposal (0.11 hr/fixture). Again, this estimate is based on the contractor-reported estimate of the labor hours required to prepare 100 lamps, ballasts, and fixtures for disposal. However, the evaluation team had no way of disaggregating these estimates to reflect only preparation of removed linear fluorescent ballasts. In this respect, the study team believes that the miscellaneous costs shown in Table 4-6 are likely to be biased high for ballast-only retrofit projects. As with lamps, the second set of miscellaneous costs ($14.63/fixture) is the rental cost of a lift from the artificial bids for high bay applications (based on an installation of 50 fixtures). As described below, physical disposal costs for entire fixtures were obtained from the joint lighting contractor survey, but ballast-only disposal fees were not.

Linear Fluorescent Fixtures

The study team's estimated installation labor hours for replacing linear fluorescent fixtures compare well to estimates from the artificial bids (0.75-0.9 hr/fixture for installation, 0.33-0.42 hr/fixture for disposal), RSMeans (1.82-1.88 hr/fixture), and DEER 2008 (0.36-0.59 hr/fixture). The average labor rate from the artificial bids ($56.31/hr) also agrees well with RSMeans ($58.27/hr) and DEER 2008 ($67.88/hr). For this measure, there are two components to the miscellaneous costs: labor for preparing removed fixtures for disposal and physical disposal fees and taxes. The first set of miscellaneous costs shown in Table 4-6 ($6.58 and $6.38/fixture for recessed and surface/suspended fixtures, respectively) reflect the labor costs associated with preparing 100 units for disposal (0.11 hr/fixture). The second set of miscellaneous costs shown in Table 4-6 ($11.95 and $18.14/fixture for recessed and surface/suspended fixtures, respectively) reflects the physical disposal fees and taxes derived from the artificial bids.[10]

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9 http://www.lamprecycling.com/articles/minimizing-lamp-and-ballast-recycling-costs/

10 There would also be a physical disposal fees and taxes for removed lamps and ballasts, but estimates specific to

High-Bay T5 Fixtures

For high-bay T5 fixtures replacing HID fixtures, the study team's estimated installation labor hours (2.02 hr/fixture) benchmarks well to the artificial bids (0.96 hr/fixture) and RSMeans (2 hr/fixture). The average labor rate from the artificial bids ($50.20/hr) also compares well to that from RSMeans ($58.27/hr). For this measure, there are three components to the miscellaneous installation costs. The first set of miscellaneous costs show in Table 4-6 ($5.69/fixture) reflect the labor costs associated with preparing 100 units for disposal (0.11 hr/fixture). The second set of miscellaneous costs ($14.63/fixture) is the rental cost of a lift based on an installation of 50 fixtures. Some facilities may have their own lift so this cost may not apply in all situations. The third set of miscellaneous costs ($17.99/fixture) reflects the physical disposal fees and taxes derived from the artificial bids.

Occupancy Sensors

The estimated installation labor hours and labor rates for installing occupancy sensors compare very well to RSMeans (1.17 hrs/sensor, $58.27/hr) and reasonably well to DEER 2008 (0.65 hrs/sensor, $67.88/hr). The miscellaneous installation costs shown in Table 4-6 reflect the taxes and the average fees for disposing of removed manual switches.

4.3 Other Nonresidential HVAC, Shell, and Lighting

4.3.1 Data Development Process

For other nonresidential HVAC measures (e.g. chillers, boilers, indirect evaporative coolers), the diversity of site conditions makes it difficult, if not impossible, to collect meaningful self-reported estimates of installation costs via large-sample telephone surveys of contractors. Similarly, the specialized labor requirements associated with nonresidential shell measures and certain types of nonresidential lighting measures make it unreasonable to attempt to collect self-reported estimates from a general survey of mechanical and electrical contractors.

To develop estimates of labor and non-equipment installation costs for these measures, the study team developed a large set of artificial project bids (41 total) and solicited itemized price quotes from multiple specialized contractors. The artificial bids were designed to identify and develop cost estimates for the major variations in site conditions that have the most influence on total project costs. Capturing the range of variations associated with major site conditions is particularly relevant for large HVAC equipment where variations in location (roof, ground, and basement) and equipment size have a major impact on total installation costs. Indeed, as Table 4-7 shows below, the study team developed six different installation scenarios for air-cooled

these products was unavailable. That said, physical disposal fees for lamps only or ballasts only would likely be less expensive that for entire fixtures.

chillers, nine different scenarios for water-cooled chillers, and nine different scenarios for steam boilers.

Note that in addition to the technology-specific framing assumptions shown in Table 4-7, the artificial bids for other nonresidential HVAC measures also included the following universal framing assumptions:

- No major electrical, mechanical, or structural changes required
- All modifications within 5-10 feet of the equipment
- Labor estimates include demolition, disposal, and commissioning.

Also note that for both air- and water-cooled chillers, the compressor type (e.g. screw, scroll, centrifugal) was not specified in the artificial bids, as HVAC contractors and engineers indicated that installation costs for chiller projects do not vary significantly by compressor type.

Table 4-7: Installation Scenarios Used in Artificial Bids for Other Nonresidential HVAC

Technology	Installation Scenario 1	Installation Scenario 2	Installation Scenario 3	Other Framing Assumptions
Demand Control Ventilation	One duct-mounted sensor installed in large packaged single-zone system to existing stand-alone DCV controller (5-10 ft. wire runs)	Four wall-mounted sensors installed into four zones of large packaged multi-zone system with existing EMS (5-10 ft. wire runs to DDC controller)	Twenty wall-mounted sensors installed into twenty zones of large packaged multi-zone system with existing EMS (5-10 ft. wire runs to DDC controller)	None
Indirect Evaporative Coolers	15,000- 22,000 CFM unit installed to replace existing fan (for make-up air only)	N/A	N/A	None
Air-Cooled Chillers	100 ton unit, installed ground level	200 ton unit, installed ground level	300 ton unit, installed ground level	Assumed no changes to cooling tower; roof location is 100 feet from the edge of the building
	100 ton unit, installed roof level	200 ton unit, installed roof level	300 ton unit, installed roof level	
Water-Cooled Chillers	100 ton unit, installed basement level	200 ton unit, installed basement level	300 ton unit, installed basement level	
	100 ton unit, installed ground level	200 ton unit, installed ground level	300 ton unit, installed ground level	
	100 ton unit, installed roof level	200 ton unit, installed roof level	300 ton unit, installed roof level	
HVAC Fan Motors >= 5 HP	5 HP unit, TEFC or open drip	25 HP unit, TEFC or open drip	50 HP unit, TEFC or open drip	None
Steam Boilers	200 MBH unit, installed basement level	1000 MBH unit, installed basement level	3000 MBH unit, installed basement level	None
	200 MBH unit, installed ground level	1000 MBH unit, installed ground level	3000 MBH unit, installed ground level	
	200 MBH unit, installed roof level	1000 MBH unit, installed roof level	3000 MBH unit, installed roof level	
Waterside Economizers	100 ton unit, with two 4" pipe runs of 50 feet	300 ton unit, with two 8" pipe runs of 50 feet	N/A	Assumed to be installed with existing chiller plant and tower and integrated with the existing EMS
	100 ton unit, with two 4" pipe runs of 100 feet	300 ton unit, with two 8" pipe runs of 100 feet		

For nonresidential shell measures and select nonresidential lighting measures, the artificial bids specified a more limited number of installation scenarios, as shown in Table 4-8 below. For these measures, the installation site conditions could be more easily generalized and efforts were focused on soliciting responses from multiple qualified contractors.

Table 4-8: Installation Scenarios Used in Artificial Bids for Nonresidential Shell and Lighting

Technology	Installation Scenario 1	Installation Scenario 2	Other Framing Assumptions
Nonresidential Building Shell			
Thermal Curtains	Installation of flat thermal blanket system with a single motor for a single zone in five greenhouses that are 40,320 sq. ft. each (each with 12 vents)	N/A	Includes installation of suspension and deployment system, installation of thermal curtains, and verification that curtains are easily deployed and opened
Reflective Film	3-story, 50,000 ft^2 building with 40 5'x5' windows (35 office windows w/9' ceilings, 5 front entrance windows where bottom of the windows are 12 feet above the floor)	N/A	Includes preparing the surface for film, installation of the film on 40 windows, and clean up
Other Nonresidential Lighting			
Bi-Level Fixtures	Replacement of 20 existing stairwell fixtures in 4-story building and with 20 bi-level fixtures	N/A	Includes commissioning, testing, and disposal of removed fixtures
HID Fixtures	Replacement of 50 mercury vapor fixtures with PSMH fixtures in a high bay warehouse	N/A	
Photocells	Installation of one photocell to work with existing time-clock that controls lobby and perimeter hallway lights in 3-story multi-family building	Installation of three photocells per floor that control perimeter lights on each floor of 3-story office building (9 photocells total, one dedicated controller)	Includes site visit to design the layout of the system; commissioning and testing

To validate the labor hours and labor rates developed from the artificial bids, the study team benchmarked each set of estimates against labor hours and labor rates from RSMeans, DEER 2008, and IOU workpapers (where available). The final data sources used to develop and validate our estimates of installation labor hours and rates for other nonresidential HVAC, shell, and lighting measures are shown in Table 4-9 below. Note that in addition to developing installation labor hours and rates, the study team also developed estimates for miscellaneous non-equipment installation costs, including miscellaneous electrical and plumbing materials, miscellaneous sheet metal, and costs associated with engineering and survey, project management, permits, insurance, bond, contingency, and warranty. Estimates for these costs were developed from the artificial bids.

Table 4-9: Final Data Sources for Installation Costs – Other Nonresidential HVAC, Shell, and Lighting

<table>
<tr><th rowspan="2">Technology</th><th colspan="2">Primary Data Source</th><th colspan="2">Validation Data Source</th></tr>
<tr><th>Labor Hours</th><th>Labor Rates</th><th>Labor Hours</th><th>Labor Rates</th></tr>
<tr><td colspan="5">Other Nonresidential HVAC</td></tr>
<tr><td>Demand Control Ventilation</td><td colspan="2" rowspan="6">Artificial bids</td><td colspan="2">Workpaper PGECOHVC143</td></tr>
<tr><td>Indirect Evaporative Coolers</td><td colspan="2">DEER 2008</td></tr>
<tr><td>Chillers (all types)</td><td colspan="2">RSMeans,
DEER 2008</td></tr>
<tr><td>HVAC Fan Motors >= 5 HP</td><td colspan="2">RSMeans</td></tr>
<tr><td>Steam Boilers</td><td colspan="2">RSMeans,
DEER 2008</td></tr>
<tr><td>Waterside Economizers</td><td colspan="2">DEER 2008</td></tr>
<tr><td colspan="5">Nonresidential Building Shell</td></tr>
<tr><td>Thermal Curtains</td><td colspan="2" rowspan="2">Artificial bids</td><td colspan="2">Workpaper PGECOAGR101</td></tr>
<tr><td>Reflective Film</td><td colspan="2">RSMeans,
DEER 2008</td></tr>
<tr><td colspan="5">Other Nonresidential Lighting</td></tr>
<tr><td>Bi-Level Fixtures</td><td colspan="2" rowspan="3">Artificial bids</td><td>RSMeans,
Contractor Survey</td><td>RSMeans</td></tr>
<tr><td>HID Fixtures</td><td colspan="2">RSMeans,
DEER 2008</td></tr>
<tr><td>Photocells</td><td colspan="2">RSMeans</td></tr>
</table>

4.3.2 Results and Findings

Table 4-10 presents the study team's estimates of non-equipment installation costs for other nonresidential HVAC, shell, and lighting measures. All labor hour estimates are expressed on a per-unit basis and include hours associated with removal of the existing equipment, installation of the new unit, and testing/commissioning, where applicable. Labor rates shown in Table 4-10 are bare labor rates, i.e. without markups.[11] The total average markup for these installation projects is shown separately and reflects the average labor and materials markup from the artificial bids (wherever available) or RSMeans. Where applicable, Table 4-10 also presents two sets of miscellaneous installation costs – those that scale with the size of the installed unit (e.g. piping, sheet metal, contingency, and warranty) and those that are fixed (e.g. crane rental, controls, and permits). The total non-equipment installation costs shown in the right-most column of Table 4-10 represent the sum of the marked-up labor costs and the marked-up, scalable miscellaneous costs but exclude miscellaneous fixed costs. To estimate total installation

[11] Note that the study team re-weighted the original estimates from the artificial bids (from Bay Area contractors) to California statewide averages using the same participation-weighted indices used to the aggregate the location-specific RSMeans city cost indices (see tables in Appendix G).

costs for a specific capacity unit, one would multiply the values in the right-most column of Table 4-10 by the capacity of the unit in question and then add the miscellaneous fixed costs.

It is important to note that while the study team has classified the costs associated with renting the heavy equipment required to remove existing units and move new units into place (e.g. cranes, forklifts, etc.) as fixed project costs, discussions with contractors indicated that these costs do tend to increase with the size of the equipment in question. However, contractors also indicated that there is no practical way to scale these costs in a reliable, generic sense as these costs are influenced by site logistics as much as equipment size. Indeed, contractors stated that they often hire professional estimators with years of hands-on experience to price these types of projects. For this study, the team accounted for these sources of variation by specifying multiple, discrete equipment capacities and access conditions. As such, the miscellaneous fixed costs shown in Table 4-10 are provided as representative costs for the specific capacity/access conditions presented but with the caveat that these expenses will be highly variable based on actual site conditions.

Table 4-10: Installation Cost Estimates for Other Nonresidential HVAC, Shell, and Lighting

Technology	Capacity Unit	Labor Hours (hr/unit)	Labor Rate ($/hr)	Misc. Costs per Unit ($/unit)	Misc. Fixed Costs per Project ($/project)	Markup (%)	Total Non-equipment Installation Costs ($/unit)
Other Nonresidential HVAC							
DCV – Single Zone	Zone	7.50	$68.18	$935.00	-	28%	$1,844.11
DCV – Four Zone	Zone	5.50	$67.14	$756.09	-	28%	$1,434.85
DCV – Twenty Zone	Zone	4.00	$67.14	$674.98	-	28%	$1,203.03
Indirect Evaporative Coolers	Ton	3.92	$66.45	$77.85	-	20%	$406.33
Air-Cooled Chillers – 100 ton ground level	Ton	0.80	$71.30	$181.94	$1,400.00	25%	$298.27
Air-Cooled Chillers – 200 ton ground level	Ton	0.44	$71.30	$137.58	$1,650.00	25%	$210.96
Air-Cooled Chillers – 300 ton ground level	Ton	0.38	$71.30	$133.78	$2,350.00	25%	$201.24
Air-Cooled Chillers – 100 ton roof level	Ton	0.83	$71.30	$182.05	$3,500.00	25%	$301.09
Air-Cooled Chillers – 200 ton roof level	Ton	0.45	$71.30	$142.78	$4,250.00	25%	$218.80
Air-Cooled Chillers – 300 ton roof level	Ton	0.40	$71.30	$138.12	$5,000.00	25%	$207.86
Water-Cooled Chillers – 100 ton ground level	Ton	1.15	$71.49	$203.90	$1,400.00	25%	$357.20
Water-Cooled Chillers – 200 ton ground level	Ton	0.79	$71.49	$179.95	$2,150.00	25%	$295.31
Water-Cooled Chillers – 300 ton ground level	Ton	0.61	$71.49	$155.02	$2,750.00	25%	$247.84
Water-Cooled Chillers – 100 ton basement level	Ton	1.59	$71.49	$215.64	$5,000.00	25%	$411.19
Water-Cooled Chillers – 200 ton basement level	Ton	1.06	$71.49	$185.50	$5,500.00	25%	$326.38
Water-Cooled Chillers – 300 ton basement level	Ton	0.74	$71.49	$159.12	$6,250.00	25%	$265.03
Water-Cooled Chillers – 100 ton roof level	Ton	1.33	$71.49	$214.78	$3,250.00	25%	$387.33
Water-Cooled Chillers – 200 ton roof level	Ton	0.86	$71.49	$183.02	$4,000.00	25%	$305.19
Water-Cooled Chillers – 300 ton roof level	Ton	0.67	$71.49	$157.44	$4,750.00	25%	$256.98
HVAC Fan Motors – 5 HP	HP	1.45	$70.14	$107.10		20%	$250.57
HVAC Fan Motors – 25 HP	HP	0.58	$70.14	$56.24		20%	$116.31
HVAC Fan Motors – 50 HP	HP	0.39	$70.14	$44.24		20%	$85.91

Table 4-10: Installation Cost Estimates for Other Nonresidential HVAC, Shell, and Lighting (continued)

Technology	Capacity Unit	Labor Hours (hr/unit)	Labor Rate ($/hr)	Misc. Costs per Unit ($/unit)	Misc. Fixed Costs per Project ($/project)	Markup (%)	Total Non-equipment Installation Costs ($/unit)
Other Nonresidential HVAC							
Steam Boilers – 200 MBH ground level	MBH	0.58	$71.33	$35.34	$0.00	28%	$97.81
Steam Boilers – 1000 MBH ground level	MBH	0.14	$71.33	$12.97	$250.00	28%	$29.08
Steam Boilers – 3000 MBH ground level	MBH	0.06	$71.33	$8.65	$900.00	28%	$16.10
Steam Boilers – 200 MBH basement level	MBH	0.60	$71.33	$37.67	$1,500.00	28%	$102.60
Steam Boilers – 1000 MBH basement level	MBH	0.16	$71.33	$14.56	$1,900.00	28%	$33.07
Steam Boilers – 3000 MBH basement level	MBH	0.06	$71.33	$8.95	$2,500.00	28%	$17.02
Steam Boilers – 200 MBH roof level	MBH	0.57	$71.33	$38.82	$1,550.00	28%	$101.57
Steam Boilers – 1000 MBH roof level	MBH	0.15	$71.33	$14.90	$1,900.00	28%	$32.77
Steam Boilers – 3000 MBH roof level	MBH	0.06	$71.33	$8.98	$2,750.00	28%	$16.53
Waterside Economizers – 100 ton, short pipe run	Ton	3.00	$70.86	$273.18	$18,450.00	28%	$618.91
Waterside Economizers – 100 ton, long pipe run	Ton	3.67	$70.86	$339.66	$18,700.00	28%	$764.20
Waterside Economizers – 300 ton, short pipe run	Ton	1.38	$70.86	$148.21	$18,950.00	28%	$313.35
Waterside Economizers – 300 ton, long pipe run	Ton	1.69	$70.86	$191.35	$19,700.00	28%	$396.51
Nonresidential Building Shell							
Thermal Curtains	Ft^2	0.0034	$39.90	$0.02	-	25%	$0.20
Reflective Film	Ft^2	0.0260	$102.47	-	-	25%	$4.72
Other Nonresidential Lighting							
Bi-level Linear Fixtures	Fixture	0.96	$56.32	$20.06+ $21.04	-	34%	$127.71
HID Fixtures	Fixture	1.31	$59.77	$29.32+ $21.80	-	20%	$155.47
Photocells – single wired sensor, no controller	Sensor	3.16	$69.64	$12.69	-	25%	$290.86
Photocells – multiple wireless sensors, dedicated controller	Sensor	1.39	$69.64	$32.20	-	25%	$160.90

The subsections below present and discuss how the estimates in Table 4-10 benchmark to corresponding estimates from RSMeans, DEER 2008, and the IOU workpapers (where available). Note that where RSMeans were used to benchmark the study team's estimates of installation labor hours, there was often a wide range of capacities associated with a given technology. In these cases, an average value was calculated and presented for benchmarking purposes.

Demand Control Ventilation

The only readily available data source to benchmark the study team's installation labor estimates for demand control ventilation was PG&E's 2013-2014 workpaper (PGECOHVC143), which specifies a total cost per unit for a single-zone system of $1,542 and a labor rate of $105/hr (equivalent to 14.7 hr/unit). This estimate of installation labor is nearly double the estimate derived from the artificial bids for a similar single-zone system installation (7.5 hr/sensor). The labor rate from the PG&E workpaper is also considerably higher than average labor rates quoted in the artificial bids ($68.18/hr). Note that in addition to the direct labor costs, there are substantial miscellaneous costs that have not been previously included in installation cost estimates for this measure. A small portion of these miscellaneous installation costs are miscellaneous consumables ($175/sensor for wiring, conduit, etc), but the vast majority of these costs is associated with engineering/survey, project management, permits, insurance, bond, contingency, and warranty.

Indirect Evaporative Coolers

For indirect evaporative coolers, installation labor hours from the artificial bids (3.92/ton) are high compared to the estimates from DEER 2008 (0.61-0.66/ton) but are comparable to installation labor estimates for the other large HVAC equipment in this study. The average labor rates from the artificial bids benchmark well compared to DEER 2008 ($66.45/hr and $67.88/hr, respectively). Miscellaneous installation costs for this technology are split roughly evenly between small tools, pipes, and fittings, and engineering/survey, project management, permits, insurance, bond, contingency, and warranty.

Air-Cooled Chillers

For air-cooled chillers, the study team's estimated installation labor hours for 100-300 ton units (0.40-0.83 hr/ton) are somewhat lower than the RSMeans estimates for 130-320 ton units (0.85-1.7 hr/ton) and substantially lower than DEER 2008 estimates (1.8 hr/ton).[12] The average labor rate from the artificial bids ($71.30/hr) compares fairly well to both those from RSMeans and

[12] The study team did not develop artificial bids for small tonnage chillers, but it is expected that lower tonnage units would have higher installation labor requirements per ton. Indeed, the RSMeans installation labor estimates for 10-50 ton units are substantially higher (4.21 hr / ton, on average) than those for higher tonnage units.

DEER 2008 ($62.46/hr and $67.88/hr, respectively). Miscellaneous fixed installation costs are for crane rental and, as indicated above, are likely to vary widely from site to site. Note that the per-unit miscellaneous installation costs are quite substantial and have not been included in previous cost studies. These costs include miscellaneous field materials, small tools and consumables, insulation, water treatment, engineering/survey, project management, permits, insurance, bond, contingency, and warranty. While total non-equipment installation costs do not vary substantially between the ground and roof installation scenarios, all project cost components are slightly higher in the roof installation scenarios.

Water-Cooled Chillers

For water-cooled chillers, the study team's estimated installation labor hours for 100-300 ton units (0.61-1.59 hr/ton) compare well to the RSMeans estimates for 80-350 ton units (average of 1.52 hr/ton) as well as the DEER 2008 estimates for screw and centrifugal chillers (1.06- 2.97 hr/ton).[13] The average labor rates from the artificial bids ($71.49/hr) are slightly higher than those from RSMeans ($60.44-$62.46/hr) and DEER 2008 ($67.88/hr). Miscellaneous fixed installation costs are for crane rental and, as indicated above, are likely to vary widely from site to site. Note that the per-unit miscellaneous installation costs are quite substantial and have not been included in previous cost studies. These costs include miscellaneous field materials, small tools and consumables, insulation, water treatment, engineering/survey, project management, permits, insurance, bond, contingency, and warranty. While total non-equipment installation costs do not vary substantially between the scenarios for a given capacity, total installation costs are generally highest for the basement scenarios, followed by roof installations and then ground mounts.

Large HVAC Fan Motors (>= 5 HP)

The only readily available data source to benchmark the study team's installation labor estimates for large HVAC fan motors was RSMeans, which specifies installation of a 7.5 HP fan motor. The capacity-normalized installation labor estimate from RSMeans (1.9 hr/HP) is significantly higher than estimates derived from the artificial bids (1.45 hr/HP for a 5-HP unit to 0.39 hr/HP for a 50-HP unit). However, the average labor rate from the artificial bids ($70.14/hr) is higher than the RSMeans estimate ($56.58/hr), such that the total installation labor cost per unit ($/HP) from the artificial bids is nearly identical to that from RSMeans for 5-10 HP motors ($102/HP and $107/HP, respectively). The study team also estimated miscellaneous per-unit costs for HVAC fan motor installations that include electrical, engineering/survey, project management, permits, insurance, bond, contingency, and warranty.

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[13] As with air-cooled chillers, the RSMeans installation labor estimates for smaller units (2-30 tons) are much higher (6.43 hr/ton, on average) and those for very large units (400- 2500 tons) are much lower (0.36 hr/ton).

Steam Boilers

The study team's estimated installation labor hours for steam boilers validate very well to RSMeans for the largest capacity units (0.06 hr/MBH) but are somewhat higher than RSMeans for the smaller capacity units (0.58 hr/MBH vs. 0.18 hr/MBH). The average labor rate from the artificial bids ($71.33/hr) compares well to both RSMeans ($62.46/hr) and DEER 2008 ($67.88/hr). Miscellaneous fixed installation costs are for crane rental and, as indicated above, are likely to vary widely from site to site. Note that the per-unit miscellaneous installation costs are quite substantial and have not been included in previous cost studies. These costs include miscellaneous field materials, small tools and consumables, insulation, piping and electrical, engineering/survey, project management, permits, insurance, bond, contingency, and warranty.

Waterside Economizers

The study team's estimated installation labor hours for installing water-side economizers (1.38 to 3.67 hr/ton) are higher than estimates from DEER 2008 (1 hr/ton). It is worth noting, however, that the artificial bids included specific requirements to include labor associated with installing piping runs of different sizes and lengths, which may explain the additional labor hours as compared to DEER 2008. The average installation labor rates from the artificial bids are similar to DEER 2008 ($67.88/hr vs. $70.86/hr, respectively). Miscellaneous fixed installation costs are considerably higher for this technology as compared to other large HVAC equipment. In addition to crane rental costs ($2,000-$5,000), the artificial bids included significant fixed installation costs for economizer controls ($8,000 to $21,500). As with other large HVAC equipment, miscellaneous per-unit costs include hangers and supports, insulation, piping and electrical, engineering/survey, project management, permits, insurance, bond, contingency, and warranty.

Thermal Curtains

The only readily available data source to benchmark the study team's installation labor estimates for thermal curtains was PG&E's 2013-2014 workpaper (PGECOAGR101) which does not separate installation labor costs from material costs. The workpaper shows a total installed cost of $1.00-$3.35/ft^2. Adding the study team's estimates of total non-equipment installation costs and material costs results in a total installed cost of $0.33-$0.61/ft^2, which is considerably lower than the workpaper estimate. However, the source data in the IOU workpapers is several years old (2006), which makes it difficult to assess its validity as a benchmark for the current market. Additionally, the range of installation labor estimates from the artificial bids was quite narrow (0.0031-0.0038 hr/ft^2 across 5 different contractors), which lends credence to the validity of those estimates.

The miscellaneous per-unit installation costs shown in Table 4-10 are for freight and taxes. Also note that the markup shown in Table 4-10 is a default value of 25 percent.

Reflective Film

The study team's estimated installation labor hours for reflective film (0.026 hr/ft^2) are slightly lower than estimates from RSMeans (0.08 hr/ft^2) and DEER 2008 (0.055-0.094 hr/ft^2). The average labor rates from the artificial bids are also quite high ($102.47/hr) in comparison to RSMeans and DEER 2008 ($52.76/hr and $56.00/hr, respectively) even after deflating the costs provided by Bay Area contractors back to the statewide average using RSMeans regional multipliers.[14] That said, however, the specific project scopes reflected in the RSMeans and DEER 2008 estimates are unclear as to whether they include preparation of the window surface, which was explicitly included in the artificial bids for this study. Also note that the markup shown in Table 4-10 is a default value of 25 percent.

Bi-level Fixtures

For bi-level fixtures, there was no benchmark data readily available from RSMeans, DEER 2008, or the IOU workpapers. However, the estimated installation labor hours for this measure from the artificial bids (0.96 hr/fixture) compare reasonably well to installation labor hours for surface-mounted T8/T5 fixtures derived from the lighting contractor survey (1.15 hr/fixture). The average labor rate from the artificial bids ($56.32/hr) benchmarks well to that from RSMeans ($58.27/hr) for standard, surface-mounted T8 fixtures.

The miscellaneous per-unit installation costs shown in Table 4-10 are broken into two components. The first component ($20.06/fixture) is for disposal preparation labor (0.36 hr/fixture), and the second component ($21.04/fixture) is for disposal fees and taxes. Finally, note that the markup shown in Table 4-10 is the average markup for materials and labor for linear fluorescent fixture installations from RSMeans.

HID Fixtures

For HID fixtures, the study team's estimated installation labor hours (1.31 hr/fixture) falls right between values from DEER 2008 (0.28-0.98 hr/fixture) and RSMeans (2.89 hr/fixture). The average labor rates from the artificial bids ($59.77/hr) also compares well to RSMeans ($58.27/hr) and DEER 2008 ($67.88/hr).

The miscellaneous per-unit installation costs shown in Table 4-10 are broken into two components. The first component ($29.32/fixture) is for physical disposal fees and taxes, and the second component ($21.80/fixture) is for lift rental (based on the installation of 50 fixtures). Note that the markup shown in Table 4-10 is the average markup for materials and labor for HID fixture installations from RSMeans.

[14] The two contractors submitting bids for this measure quoted hourly rates of $148/hr and $143/hr.

Photocells

For photocells, the study team's estimated installation labor hours for the sensor-only scenario (3.16 hr/sensor) are considerably higher than the estimate from RSMeans (1.19 hr/sensor). Interestingly, the scenario with installation multiple wireless photocells and a dedicated controller is much closer to the RSMeans estimate on a per sensor basis (1.39 hr/sensor), despite the additional requirements to install the dedicated controller. In this sense, the difference in installation labor requirements (on a per-sensor basis) between the two scenarios appears to be related largely to the labor associated with installing the wire run between the sensor and the time-clock. The individual contractor responses to the artificial bids ranged from 0.55-1.94 hr/sensor for the multi-sensor scenario and 2.0- 4.25 hr/sensor for the single sensor scenario.[15] The average labor rate from the artificial bids is also somewhat high compared to RSMeans ($69.64/hr vs. $58.27/hr). The miscellaneous per-unit installation costs shown in Table 4-10 are for disposal fees and taxes. Note that the markup shown in Table 4-10 is the average markup for materials and labor for photocell installations from RSMeans.

4.4 Water Heating, Other Residential HVAC, Other Commercial Ventilation, and MSB Lamps Installation Costs

4.4.1 Data Development Process

For water heating, other residential HVAC, and other commercial ventilation technologies and medium screw-based (MSB) lamps, the study team relied primarily on non-equipment installation cost estimates from RSMeans, with supporting estimates drawn from DEER 2008, IOU workpapers, online resources, and the TSDs developed and published by the USDOE.

For water heating, other residential HVAC, and other commercial ventilation technologies in particular, the study team used the RSMeans installation labor estimates for a wide range of equipment capacities to develop models of installation labor requirements as continuous functions of equipment capacity. This approach is analogous to the approach used in many of the USDOE's TSDs when adapting installation labor estimates from RSMeans. For this study, the study team fit linear models to the RSMeans data, with the sole exception being direct evaporative coolers for which the study team fit an exponential model.

Table 4-11 below shows the technologies where the study team developed models of installation labor hours using RSMeans data, the specific capacity ranges (and number of RSMeans estimates) that formed the basis for the models, and the resulting model of installation labor hours.

[15] These ranges are not inclusive of two clear outliers that were removed because the contractors appeared to interpret the project scope incorrectly.

Note that in Table 4-11, the capacity unit for direct evaporative coolers is shown as tons cooling. This equipment is typically rated on a CFM basis. Indeed, the study team's unit equipment price estimates for this technology presented in Section 3 are based on capacity ratings in terms of CFM. However, RSMeans specifies the capacity for this equipment on a tons-cooling basis. In order to develop a model of installation labor hours that could be used in combination with the CFM-based unit price model, the study team developed an estimate of CFM-tonnage equivalency (1,170 CFM = 1 ton).[16]

Table 4-11: Installation Labor Hours Models Developed for Water Heating, Other Residential HVAC, and Other Commercial Ventilation Based on RSMeans Data

Technology	Capacity Unit	Capacity Range Used to Estimate Model (N)	Installation Hours Model
Other Residential HVAC			
Gas Furnaces	MBH	45-150 (11)	Hr = 0.017(MBH) + 3.2398
Direct Evaporative Coolers	Ton	1.5-12 (12)	$Hr = 2.7446e^{0.1427(tons)}$
Other Commercial Ventilation			
Fan VFDs (>50 HP)	HP	60-200 (5)	Hr = 0.0796(HP) + 30.5
Fan VFDs (15-50 HP)	HP	15-50 (5)	Hr = 0.3405(HP) + 12.225
Fan VFDs (3-10 HP)	HP	3-10 (4)	Hr = 0.3328(HP) + 8.8483
Nonres HVAC Fan Motors (<5 HP)	HP	0.5-3 (3)	Hr = 1.0476(HP) + 8.1323
Water Heating			
Gas Storage WH (<75 MBH)	Gallons	30-100 (6)	Hr = 0.0315(gal) + 2.9443
Gas Storage WH (75-250 MBH)	MBH	75-250 (9)	Hr = 0.0655(MBH) - 0.3869
Gas Storage WH (260-725 MBH)	MBH	260-725 (4)	Hr = 0.0153(MBH) + 15.304
Gas Tankless WH	GPM	3.2-9.5 (4)	Hr = 0.1395(GPM) + 3.4545
Electric Storage WH (<75 MBH)	Gallons	20-120 (7)	Hr = 0.0222(gal) + 3.0515
SHW Boilers <300 MBH	MBH	80-280 (7)	Hr = 0.0638(MBH) + 18.887
SHW Boilers >=300 MBH	MBH	320-2856 (12)	Hr = 0.0471(MBH) + 31.307
Condensing SHW Boilers	MBH	42-194 (7)	Hr = 0.070(MBH) + 5.6985

For the other measures in this group (whole house fans, heat pump water heaters, residential HVAC fan motors, batt insulation, and MSB lamps), the study team used point estimates or simple averages of installation labor costs (as opposed to developing continuous functions) from RSMeans. The three exceptions to this were for whole house fans, heat pump water heaters, and residential HVAC fan motors. For whole house fans, the study team relied upon a point estimate developed by DEG based on their professional experience as industry experts in the development and diffusion of this particular technology, particularly in California. DEG estimated installation labor for whole house fans to be 6 hours per fan on average and indicated that that estimate

[16] Workpapers specify 1,300 CFM is approximately equivalent to 1 cooling ton at 0.1" static pressure. Title 20 requires performance metrics for DEC to be specified at 0.3" static pressure. On average, it was found that the difference between CFM delivered at 0.1" static pressure and 0.3" static pressure was a factor of 0.9 (CFM@0.1"x0.9=CFM@0.3").

should be representative of a large fraction of whole house fan installations in California. For heat pump water heaters, the study team used the installation labor estimates developed by the USDOE and published in the TSD associated with the most recent standards rulemaking for residential heating equipment.[17] The TSD installation cost data is based on a 2004 study by the CEC of 20 heat pump water heater installations in California. The TSD installation labor cost estimates include adders for condensate pump and venting and additional labor as compared to an electric storage unit. Finally, for residential HVAC fan motors, the study team used installation labor estimates derived from a 2014 field study by the National Renewable Energy Laboratory (NREL) on retrofit installations of eight variable speed furnace fan motors in New York. This study suggests there is some variation in labor hours required based on mounting type (belly band or mounting bracket), but due to the small sample size of those field tests, the study team applied the simple average of installation labor hours across those eight test sites.[18]

For batt insulation, installation labor hours were estimated from the average of eight RSMeans measures for floor, ceiling, and wall batt insulation measures. The product specifications in the associated measures ranged from 3.5” to 12” of insulation (R-13 to R-38) and included paper, foil, kraft, and unfaced backing types. However, the RSMeans installation labor hour estimates across these specifications do not vary significantly, thus the study team used a simple average.

For MSB reflector lamps, installation labor hours were estimated from the average of three RSMeans measures for LED reflector lamps: MR16, PAR20, and PAR30.[19] The installation cost estimates for these three LED reflector lamp measures were assumed to be representative of all types of MSB reflector lamps (incandescent, CFL, or LED). Similarly, installation labor hours for MSB globe lamps were estimated from the RSMeans measure for LED globe lamps.[20] The installation costs for this measure were assumed to be representative of all types of MSB globe lamps (incandescent, CFL, or LED).

For MSB A-lamps, twisters, and torpedo lamps, RSMeans does not include installation cost estimates for these specific lamps types. To estimate the installation costs for these measures, the study team used the average installation costs of the following three measures available in RSMeans: twin-tube CFL lamps, double twin-tube CFL lamps, and A60-shape LED lamps. The average installation costs for these measures were assumed to be representative of all types of MSB A-lamps, twisters, and torpedo lamps (incandescent, CFL, or LED).

For HID lamps, the study team’s estimated installation labor costs for two distinct scenarios: installation of high-wattage HID lamps (>1000 W) and installation of low-wattage HID lamps

17 http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/27

18 http://www.nrel.gov/docs/fy14osti/60760.pdf

19 RSMeans does not include installation cost estimates for CFL or incandescent reflector lamps.

20 RSMeans does not include installation cost estimates for CFL or incandescent globe lamps.

(<1000 W). Installation labor costs for the high-wattage scenario were estimated from the average of three RSMeans measures: 1000 W mercury vapor lamps with a mogul base, 1000-1500 W metal halide lamps with a mogul base, and 1000 W high pressure sodium lamps with a mogul base. Installation labor costs for the low-wattage scenario were estimated from the average of four RSMeans measures: 100-400 W mercury vapor bulbs with a mogul base, 175-400 W metal halide bulbs with a mogul base, 70-400 W high pressure sodium bulbs with a mogul base, and 35-55 W low pressure sodium bulbs with an MSB base. It should be noted that within each scenario, all of the associated installation labor hour estimates in RSMeans for the different bulb types were identical.

To validate the labor hours and labor rates developed from the artificial bids, the study team benchmarked each set of estimates against labor hours and labor rates from DEER 2008, IOU workpapers (where available), and USDOE TSDs (where available). The final data sources used to develop and validate our estimates of installation labor hours and rates for water heating, other residential HVAC, other commercial ventilation, and MSB lamp technologies are shown in Table 4-12 below. Note that in addition to developing installation labor hours and rates, the study team also developed estimates for miscellaneous non-equipment installation costs for heat pump water heaters (from the USDOE TSD) and service hot water (SHW) boilers (from the artificial bids for steam boilers), including miscellaneous electrical and plumbing materials, and costs associated with engineering and survey, project management, permits, insurance, bond, contingency, and warranty.

Table 4-12: Final Data Sources for Installation Costs – Water Heating, Other Residential HVAC, Other Commercial Ventilation and MSB Lamps

Technology	Primary Data Source		Validation Data Source	
	Labor Hours	Labor Rates	Labor Hours	Labor Rates
Other Residential HVAC				
Whole House Fans	DEG	RSMeans	RSMeans, HomeWyse.com	None
Res. Gas Furnaces	RSMeans		DEER 2008	
Direct Evaporative Coolers			Workpaper SCE13HCO13	
Res. HVAC Fan Motors	NREL	RSMeans	RSMeans	
Other Commercial Ventilation				
Fan VFDs	RSMeans		None	
Nonres HVAC Fan Motors (<5 HP)				
Water Heating				
Storage Water Heaters (all)	RSMeans		DEER 2008, USDOE TSD	
Tankless Water Heaters				
Heat Pump Water Heaters	USDOE TSD		None	
SHW Boilers (all types)	RSMeans		DEER 2008, USDOE TSD, Artificial Bids	DEER 2008, USDOE TSD
Building Shell				
Batt Insulation	RSMeans		DEER 2008	
Lighting				
MSB Lamps (all types)	RSMeans		DEER 2008	

4.4.2 Results and Findings

Table 4-13 presents the study team's estimates of non-equipment installation costs for other nonresidential HVAC, shell, and lighting measures. All labor hour estimates are expressed on a per-unit basis. Labor rates shown in Table 4-13 are bare labor rates, i.e. without markups. The total average markup for these installation projects is shown separately and reflects the average labor and materials markup from RSMeans (except where noted in the subsections below). The total non-equipment installation costs shown in the right-most column of Table 4-13 represent the sum of the marked-up labor costs and the marked-up miscellaneous non-equipment costs.

Table 4-13: Installation Cost Estimates for Water Heating, Other Residential HVAC, Other Commercial Ventilation and MSB Lamps

Technology	Unit	Labor Hours (hr/unit)	Labor Rate ($/hr)	Misc. Costs per Unit ($/unit)	Markup (%)	Total Non-equipment Installation Costs ($/unit)
Other Residential HVAC						
Whole House Fans	Fan	6	$58.27	-	15%	$402.09
Gas Furnaces	MBH	0.06	$55.56	-	23%	$4.02
Res HVAC Fan Motors	Unit	2.59	$56.58	-	18%	$173.18
Direct Evaporative Coolers	Ton	1.35	$55.56	-	22%	$91.82
Other Commercial Ventilation						
Fan VFDs (> 50 HP)	HP	0.40	$65.31	-	20%	$30.98
Fan VFDs (15-50 HP)	HP	0.82	$58.27	-	20%	$57.26
Fan VFDs (3-10 HP)	HP	2.03	$58.27	-	20%	$141.95
Nonres HVAC Fan Motors <5 HP	HP	9.90	$56.58	-	20%	$672.28
Water Heating						
Gas Storage WH (<75 MBH, 50 gal)	Unit	4.52	$64.62	-	21%	$353.42
Gas Storage WH (150 MBH)	Unit	9.44	$64.62	-	15%	$701.51
Gas Storage WH (500 MBH)	Unit	22.95	$58.17	-	15%	$1,535.25
Gas Tankless WH (4 gpm)	Unit	4.01	$64.62	-	26%	$326.70
Electric Storage WH (50 gal)	Unit	4.16	$64.62	-	23%	$330.77
Heat Pump WH	Unit	4.25 + 3.7	$47.06	$153.58 + $115.00	25%	$442.00 + $361.42
SHW Boilers <300 MBH (ground)	MBH	0.196	$62.46	$28.72	28%	$52.41
SHW Boilers <300 MBH (basement)				$31.04		$55.39
SHW Boilers <300 MBH (roof)				$30.70		$54.95
SHW Boilers >=300 MBH (1000 MBH ground)	MBH	0.092	$62.46	$11.42	28%	$21.87
SHW Boilers >=300 MBH (3000 MBH ground)				$8.05		$17.58
SHW Boilers >=300 MBH (1000 MBH basement)				$13.01		$23.90
SHW Boilers >=300 MBH (3000 MBH basement)				$8.36		$17.97
SHW Boilers >=300 MBH (1000 MBH roof)				$13.00		$23.88
SHW Boilers >=300 MBH (3000 MBH roof)				$8.27		$17.86
Condensing SHW Boilers (ground)	MBH	0.136	$59.98	$28.72	28%	$47.03
Condensing SHW Boilers (basement)				$31.04		$49.99
Condensing SHW Boilers (roof)				$120.82		$164.46

Table 4-13: Installation Cost Estimates for Water Heating, Other Residential HVAC, Other Commercial Ventilation and MSB Lamps (continued)

Technology	Unit	Labor Hours (hr/unit)	Labor Rate ($/hr)	Misc. Costs per Unit ($/unit)	Markup (%)	Total Non-equipment Installation Costs ($/unit)
Building Shell						
Batt Insulation	Ft^2	0.011	$54.71	-	38%	$0.81
MSB Lamps						
MSB A-lamps/twisters/torpedoes	Lamp	0.08	$58.27	-	24%	$5.75
MSB Reflectors	Lamp	0.06	$58.27	-	24%	$4.48
MSB Globes	Lamp	0.05	$58.27	-	24%	$3.61
HID Lamps (>=1000 watts)	Lamp	0.40	$58.27	-	24%	$28.90
HID Lamps (<1000 watts)	Lamp	0.27	$58.27	-	24%	$19.27

Whole House Fans

The study team's estimated installation labor hours for whole house fans (6 hr/fan) is somewhat higher than a generic installation cost estimate developed by HomeWyse.com (4 hr/fan) but significantly higher than the RSMeans estimate (0.5-2 hr/fan).[21] No other benchmark data were readily available for this measure. Given DEG's extensive experience in the development, testing, and diffusion of this particular technology in California, the study team found no compelling evidence that invalidated their estimate of installation labor hours.

Gas Furnaces

The average installation labor hours estimates from RSMeans for gas furnaces (0.06 hr/MBH) benchmarks well to the corresponding estimate from DEER 2008 (0.086 hr/MBH). For the capacity range in question, RSMeans estimates ranged from 0.04 to 0.09 hr/MBH. The RSMeans labor rate ($55.56/hr) for this measure is lower than the labor rate used in DEER 2008 ($67.88/hr).

Residential and Commercial HVAC Fan Motors (<5 HP) and VFDs

There was little benchmark data readily available for these measures. The IOU workpapers for these measures reference installation labor estimates from RSMeans 2002. Note that for small HVAC fan motors, the installation labor hours provided in RSMeans are highly variable on a per-unit basis (3.7-16 hr/HP) across fan motors in the 0.5-3 HP range. However, industry experts and energy efficiency stakeholders in California indicated that installation costs for small HVAC fan motors do not scale by HP, as the RSMeans data would suggest, and are better estimated on a per-unit basis. The average per-unit labor hours derived from the 2014 NREL

21 http://www.homewyse.com/services/cost_to_install_whole_house_fan.html

field study (2.59 hr/unit) is considerably lower than the estimates in RSMeans but is consistent with the experiences of industry experts and stakeholders.

Direct Evaporative Coolers

The average installation labor hours for direct evaporative coolers from RSMeans (1.35 hr/ton) falls within the range of installation labor hours estimated in SCE's corresponding workpaper (1.14-8.54 hr/ton). However, it should be noted that SCE's workpaper specifies a large range of installation labor requirements that varies by building type and vintage.[22] The RSMeans labor rate ($55.56/hr) benchmarks well to the labor rate used in SCE's workpaper ($55.26/hr).

Small Gas Storage Water Heaters

The installation labor hours for a typical 50-gallon small gas storage water heaters from RSMeans (4.52 hr/unit) benchmarks well to the estimate used in the USDOE's TSD (4.75 hr/unit) but is high compared to the value used in DEER 2008 (2.25 hr/unit). The USDOE's TSD also specifies an adder for the larger units in this category (66- or 75-gallon units) or installations attic spaces equal to an additional one hr/unit (i.e., 5.75 hr/unit) which is consistent with the installation labor model developed from RSMeans data predicts for a 75-gallon unit (5.31 hr/unit). The RSMeans labor rate for this measure ($64.62/hr) is somewhat higher than the labor rate used in DEER 2008 ($59/hr) and the USDOE's TSD ($48.38/hr).

Large Gas Storage Water Heaters

Due to the wide capacity range, two different equations were developed from the RSMeans data for large gas storage water heaters (one for 75-250 MBH units and one for 251-725 MBH units). The labor hours estimates for a 150 MBH unit and a 500 MBH unit using these equations (9.44 hr/unit and 22.95 hr/unit, respectively) are very high compared to DEER 2008 and the estimates in the USDOE's TSD (2.25 hr/unit and 5.75 hr/unit). However, the DEER 2008 and USDOE benchmarks are for conventional (small) gas storage water heaters, which would be expected to be considerably lower than for significantly larger units. The RSMeans labor rates for installing these two categories of large storage water heaters ($64.62/hr and $58.17/hr) are generally in line with those used in DEER 2008 ($59/hr) but are somewhat higher than those used in the USDOE's TSD ($48.38/hr).

Tankless Water Heaters

The installation labor hours for a four gallons-per-minute (GPM) tankless water heater from RSMeans (4.01 hr/unit) is significantly higher that the estimate from DEER 2008 (2.25 hr/unit). The RSMeans labor rate ($64.62/hr) for installation of a tankless water heater is also slightly

[22] Building type and vintage affect the conversion of $/CFM to $/ton to $/1000sqft used in SCE's workpaper.

higher than the labor rate in DEER 2008 ($59/hr). The USDOE's TSD does not provide an explicit build-up of installation labor hours and rates for this technology but does provide an estimate of total non-equipment installation costs. This estimate ($967/unit) is more than twice the study team's estimated total non-equipment installation cost ($326.70/unit). From this perspective, the RSMeans estimates of total non-equipment installation costs for tankless water heaters fall directly in between available benchmarks from DEER 2008 and the USDOE's TSD.

Electric Storage Water Heaters

The installation labor hours from RSMeans for a typical 50-gallon electric storage water heater (4.16 hr/unit) is slightly higher than the corresponding estimates from the USDOE's TSD (3.25 hr/unit) but is significantly higher than the estimate from DEER 2008 (2.25 hr/unit). The USDOE's TSD also specifies an adder for larger units (66-, 75-, and 119-gallon units) or installations in attic spaces equal to an additional one hr/unit. The RSMeans labor rate ($64.62/hr) is slightly higher than the labor rate used in DEER 2008 ($59/hr) and the USDOE's TSD ($40.64/hr).

Heat Pump Water Heaters

There were no benchmark data readily available for heat pump water heaters. The USDOE's TSD estimate of installation labor hours (4.25 hr/unit) includes the base installation costs for an electric storage water heater, plus a one-hour adder for the additional requirements of a heat pump water heater. The miscellaneous non-equipment installation costs shown in Table 4-13 are for a condensate pump ($153.58/unit) and a new venting system ($115/unit). The additional installation labor hours shown in Table 4-13 (3.7 hr/unit) are also associated with installation of the venting system. The markup for this measure is a default value of 25 percent.

Non-condensing SHW Boilers

The average installation labor hours for non-condensing SHW boilers from RSMeans for 80-280 MBH units (0.196 hr/MBH) and 320-2856 MBH units (0.092 hr/MBH) benchmark relatively well to the estimates from DEER 2008 (0.3 hr/MBH and 0.07-0.14 hr/MBH, respectively). The USDOE's TSD also uses RSMeans labor estimates and provides similar results to the model developed by the study team (based on the same data). Miscellaneous per-unit costs and fixed costs (crane/rigging) for the installation of non-condensing SHW boilers are assumed to be the same as those for 1000 MBH steam boilers in the ground, basement, and roof installation scenarios presented earlier. The TSD estimates for miscellaneous per-unit installation costs for 80-280 MBH units ($6.50/MBH) and 320-2856 MBH units ($1.30/MBH) are low compared to estimates derived from the artificial bids for steam boilers. However, the TSD does not include engineering, project management, warranty, and other miscellaneous project costs.[23] The

[23] The USDOE's TSD includes the following non-equipment costs for all sizes of SHW boilers: $500 for controls

RSMeans labor rate ($62.46/hr) benchmarks well to the labor rate used in DEER 2008 ($67.88/hr). The markup for this measure reflects the average labor rate from the artificial bids for steam boilers.

Condensing SWH Boilers

The average installation labor hours for condensing SHW boilers from RSMeans for 42-194 MBH units (0.136/MBH) benchmarks well to DEER 2008 (0.07-0.3 hr/MBH).[24] Miscellaneous per-unit and fixed costs for condensing SHW boilers are assumed to be the same as for steam boilers in the 1000 MBH ground, basement, and roof scenarios. The TSD estimates for per-unit miscellaneous installation costs ($6.50/MBH) are low compared to the estimates derived from the artificial bids for steam boilers. However, the TSD does not include engineering, project management, warranty, and other miscellaneous project costs.[25] The RSMeans labor rate ($59.98/hr) is somewhat low compared to the labor rate used in DEER 2008 ($67.88/hr). The markup for this measure reflects the average labor rate from the artificial bids for steam boilers.

Batt Insulation

The average installation labor hours from RSMeans (0.011 hr/ft^2) benchmarks well to the estimate from DEER 2008 (0.01-0.02 hr/ft^2). The average RSMeans labor rate for this measure ($54.71/hr) is significantly higher than the labor rate used in DEER 2008 ($44.00/hr).

MSB Lamps

The average installation labor hours from RSMeans for MSB lamps varies from 0.05 hr/lamp to 0.08 hr/lamp, depending on the lamp shape (e.g. A-lamp vs. reflector vs. globe) which is likely related to the access conditions typically associated with each particular lamp type. These averages from RSMeans benchmark well to the DEER 2008 estimates for screw-in CFLs (0.08 hr/lamp). The RSMeans labor rate ($58.27/hr) is slightly lower compared to the labor rate used in DEER 2008 ($67.88/hr).

HID Lamps

The average installation labor hours from RSMeans for HID lamps (0.4 hr/lamp for >1000 W lamps, 0.27 hr/lamp for <1000 W lamps) compare well to the DEER 2008 estimates (0.25-0.98

modifications, $300 for installation of condensate drain lines, and $500 for installation costs specific to replacement of existing boilers with high efficiency boilers.

24 Note that the DEER 2008 estimate is not specific to condensing SHW boilers.

25 The USDOE's TSD includes the following non-equipment costs for all sizes of SHW boilers: $500 for controls modifications, $300 for installation of condensate drain lines, and $500 for installation costs specific to replacement of existing boilers with high efficiency boilers.

hr/lamp). The RSMeans labor rate ($58.27/hr) is slightly lower compared to the labor rate used in DEER 2008 ($67.88/hr).

4.5 Commercial and Industrial Refrigeration

Several in-scope commercial and industrial refrigeration measures are, in reality, more akin to “projects” rather than one-for-one replacements or add-ons and involve multiple components and highly specialized, turnkey labor. For this reason, the study team developed built-up labor cost estimates for these measures.

Appendix C provides a full-length report developed by the study team that provides detailed documentation and discussion of the data sources and analyses used to develop the built-up cost estimates for commercial and industrial refrigeration measures.[26] The discussion presented below is synthesized from that report.

4.5.1 Data Development Process

The data development and labor cost estimation approach for each commercial and industrial refrigeration measure gave consideration to the cost elements which were most important in order to avoid details that minimally affect bottom-line measure cost. In some instances, this required more focus on the hardware costs, and in others and more nuanced understanding of installation labor or other factors. Most measures required engineering a sample system configuration and hardware selections. For all measures, the study team interviewed equipment manufacturers and installers to refine their understanding of equipment, material, and labor cost variations for in-scope measures and to help define the “cost basis” of each measure, which for most in-scope measures meant defining prototypical project specifications.

The primary and validation data sources used to estimate installation labor costs were largely the same across all in-scope measures. Primary data was collected from manufacturer quotes and artificial project bids. Validation data was collected from contractor quotes, as well as previous DEER estimates. See Appendix C for measure-specific details on the data development process and the specific cost bases used for commercial and industrial refrigeration measures

In developing the installation cost estimates for commercial and industrial refrigeration measures, the study team identified several findings related to industry standard practice and market assessment that are directly relevant to estimating installation costs for particular commercial and industrial refrigeration measures going forward. These include:

[26] This report was authored by VACOM, who conducted the commercial and industrial refrigeration price data collection and analysis for this study on a turnkey basis.

- Installation labor costs for LED display case lighting can vary significantly. This is related to the wide variation in light receptacle and attachment configuration to the mullion bulkhead, which sometimes requires re-wiring.
- Microprocessor-based compressor controls with embedded FSP logic have been ubiquitous on nearly all supermarket parallel-rack systems installed in at least the past 25 years, and the study team knows of no examples of systems in use today without them. The logic to float the suction pressure, however, is not always in use or properly commissioned. The commercial system cost build-up for this measure therefore only includes the labor to re-commission the FSP logic on the existing microprocessor controller.

4.5.2 Results and Findings

Table 4-14 presents the study team's estimates of non-equipment installation costs for commercial and industrial refrigeration measures, along with benchmark estimates available from DEER 2008 and DEER 2005. Note that DEER 2001 did not include estimates for any of the measures shown in Table 4-14. As the table shows, the installation cost estimates are largely consistent with previous DEER estimates (where directly comparable), with a few key exceptions. Again, additional detail on the specific cost bases used by the study team to develop these installation cost estimates is provided in Appendix C, as well as additional benchmarking results from price quotes solicited from equipment installers and contractors.

For ECM fan motors, the study team's installation cost estimates are very consistent with DEER 2005 estimates, with significantly lower installation costs for fan motor retrofits in open and doored display cases compared to walk-in cooler boxes. In comparison, the DEER 2008 installation cost estimates for these measures are significantly higher and do not vary across installation scenarios.

For medium-temperature glass door measures, the study team's installation cost estimates are also very consistent with estimates from DEER 2008 and DEER 2005, with the key exception of the retrofit case, where the study team's estimate is roughly 75 percent higher than the DEER 2005 estimate. This difference appears to be largely due to the inclusion of several installation activities unaccounted for in previous DEER estimates for this measure, including survey and engineering, adjusting thermostatic expansion valves, replacing and adjusting suction line risers, suction group changes, and re-commissioning EMS systems.

For auto-closer measures, the study team's installation cost estimates for "person-width" doors (<42") fall directly between the previous estimates from DEER 2008 and DEER 2005. For "cargo-width" doors (>42"), the study team's estimates are twice those for person-width doors due to higher installation labor requirements and large contingency fees due to the significantly higher cost of armature-style door closers (for cargo-width doors) compared to snubber-type door closers (for person-width doors).

For evaporator fan control measures, the study team's installation cost estimates for fan motors less than one HP are roughly twice those from DEER 2008 and DEER 2005. This difference appears to be due to significantly lower labor rates used in the previous DEER estimates ($65.62/hr) compared to those used in the current estimate ($84.84/hr).

Table 4-14: Installation Cost Estimates for Commercial/Industrial Refrigeration

Measure Source	Measure Description	Cost Unit	Cost Estimate	DEER 2008	DEER 2005
DEER measures	ECM fan motors for walk-in coolers	Per motor	$42.81	$73.65	$41.89
	ECM fan motors for doored display case	Per motor	$18.30	$73.65	$13.67
	ECM fan motors for open display case	Per motor	$19.29	$73.65	$13.67
	Medium temp glass doors (retrofit)	Per linear ft upright display case	$176.98	N/A	$99.81
	Medium temp glass doors (new)	Per linear ft upright display case	$324.48	$331.41	$329.66
	Auto-closers on main cooler/freezer doors, <42" wide	Per cooler door	$70.78	$36.82	$110.63
Example Measure	Auto-closers on main cooler/freezer doors, >42" wide	Per cooler door	$140.36	$36.82	$110.63
DEER measure	Evaporator fan control on walk-in coolers/freezers (<1 hp)	Per motor	$199.55	$92.06	$83.25
Example Measure	Evaporator fan control on walk-in coolers/freezers (>1 hp)	Per motor	$762.14	$92.06	$83.25
DEER measures	Floating suction pressure (retrofit)	Per suction group	$5,460	N/A	$26.78*
	Floating head pressure (FHP), fixed setpoint (FSP) (air-cooled, retrofit)	Per discharge group	$4,673	N/A	$27.90*
	FHP, FSP (evap-cooled, retrofit)	Per discharge group	$4,673	N/A	$27.90*
	FHP, variable setpoint (VSP) (air-cooled, retrofit)	Per discharge group	$4,882	N/A	$40.92*
	FHP, VSP (evap-cooled, retrofit)	Per discharge group	$4,897	N/A	$40.92*
	FHP, VSP & variable speed (VS) (air-cooled, retrofit)	Per discharge group	$8,184	N/A	$91.66*
	FHP, VSP & VS (evap-cooled, retrofit)	Per discharge group	$8,241	N/A	$68.92*
Example Measures	Strip curtains on walk-Ins (doors <36" wide)	Per square foot	$3.45	$2.72	N/A
	Strip curtains on walk-Ins (doors >36" wide)	Per square foot	$2.04	$2.72	N/A
	LED lights in reach-in display cases	Per fixture	$40.24	N/A	N/A
	LED lights in open display cases	Per fixture	$30.70	N/A	N/A
DEER measures	Floating suction pressure (retrofit) – industrial	Per suction group	$7,877	N/A	$26.78*
	FHP, FSP (evap-cooled, retrofit) – industrial	Per discharge group	$4,574	N/A	$27.90*
	FHP, VSP (evap-cooled, retrofit) – industrial	Per discharge group	$4,798	N/A	$40.92*
	FHP, VSP & VS (evap-cooled, retrofit) - industrial	Per discharge group	$8,241	N/A	$68.92*

* DEER 2005 costs for these measures were expressed as per ton, rather than per discharge group or per suction group.

For FSP and FHP measures, the study team's installation cost estimates are not directly comparable to previous DEER estimates since they are normalized per discharge group or suction group rather than per ton design load. Since the hardware requirements for these types of controls are mostly the same for nearly all sizes of systems, the installation costs for these measures are mostly invariable relative to design load, and the study team therefore recommends changing the cost unit to number of suction groups (FSP) or discharge groups (FHP). Also note that the study team developed separate installation cost estimates for commercial supermarket versus industrial refrigerated warehouse applications. Previous DEER estimates did not differentiate equipment costs for FSP and FHP measures across these two distinct contexts.

For strip curtains, the study team's equipment cost estimates are comparable to previous DEER estimates for both "standard" and "custom" sized doors.

For LED display case lighting, no previous DEER estimates are available to benchmark the study team's installation cost estimates. However, the study team's estimates fall within the range of price quotes gathered from five installers, albeit on the higher end of the range.

4.6 HVAC Maintenance and SHW Distribution

For HVAC maintenance measures, SHW distribution measures, and appliance recycling, the study team assembled installation cost data from direct installation (DI) contractors who provided DI services to the IOUs over the past two program cycles (2010-2012 and 2013-2014). The study team acquired these data via formal data request to the IOUs, and the micro data provided by the IOUs is confidential. Validation benchmarks were compiled from previous DEER and IOU workpapers (HVAC maintenance), as well as RSMeans and Grainger (pipe insulation).

4.6.1 Data Development Process

For HVAC maintenance measures (duct testing and sealing, coil cleaning, and refrigerant charging and adjustment), it is difficult if not impossible to cost-effectively develop parameters for average site conditions and specify the individual maintenance activities that field technicians may pursue, since they include a wide variety of possible interventions such as over/under charge corrections of various magnitudes, light versus deep coil cleaning, etc. Due to the ambiguity of these analytic boundaries, the study team determined that it would not be feasible to use artificial project bids, contractor quotes, or contractor telephone surveys to develop average installation cost estimates for these measures and relied on as much "market data" that could be easily assembled (in the form of recent DI prices to the IOUs).

For appliance recycling measures, the amount of installation cost data available is severely limited by the fact that only two contractors (JACO and ARCA) handle the IOUs' appliance recycling programs statewide. In this sense, there is no other contractor "population" from which to acquire installation cost estimates, and the resulting cost data set is extremely small.

4.6.2 Results and Findings

Table 4-15 below shows the study team's installation cost estimates for HVAC maintenance measures, and SHW distribution measures. As the table shows, the study team's estimates are largely consistent with previous DEER estimates, with one key exception as described below. Note that no benchmarks were readily available for coil cleaning or economizer repair.

Table 4-15: Installation Cost Estimates for HVAC Maintenance, SHW Distribution, Pool Covers, and Appliance Recycling

Measure Source	Measure Description	Cost Unit	Sample N	Cost Estimate	DEER 2008	DEER 2005	DEER 2001	Other
DEER measures	Duct Testing and Sealing	Per dwelling	2	$181.24	$441.87	$91.24	N/A	N/A
	Refrigerant Charging and Adjustment	Per ton cooling served	10	$26.78	$36.82	$28.23	N/A	N/A
Example Measures	Evaporator Coil Cleaning (nonres)	Per ton cooling served	5	$33.69	N/A	$35.11	N/A	N/A
	Condenser Coil Cleaning (nonres)	Per ton cooling served	6	$25.65	N/A	N/A	N/A	N/A
	Economizer repair	Per ton cooling served	11	$19.78	$73.65	$41.71	N/A	N/A
DEER measures	Pipe Insulation (SHW)	Per linear foot	3	$13.77 *	$3.63	$2.44	N/A	$14.83**
	Lowflow Showerheads	Per showerhead	9	$15.67	$16.74	$15.00	$10.77	N/A

* RSMeans 2013 (installation of closed cell foam insulation on SHW pipes, averaged across estimates for 0.5" to 1.5" pipes).

** Simple average of the 3 "top seller" qualifying units from Grainger and 10 "top seller" qualifying units from Home Depot. Note this average reflects full retail prices, rather than DI contractor bulk prices to the IOUs.

For duct testing and sealing, the study team's installation cost estimate is roughly twice that from DEER 2005 but less than half of the DEER 2008 estimate. From these benchmarks alone, it is thus difficult to assess the validity of the study team's estimate based on a small sample of DI prices. Indeed, the installation labor cost estimate shown in Table 4-15 is only based on prices from two DI contractors. However, the IOUs provided additional price data from five DI contractors for which only total labor plus materials prices were provided. Across the larger sample of seven DI contractors, the average total labor plus materials costs for this measure was $270/dwelling, which is very consistent with the total of the separate labor and materials cost averages from the two DI contractors that provided itemized prices ($252/dwelling).

For SHW pipe insulation, the study team's installation labor cost estimate is an order of magnitude higher than previous DEER estimates ($13/ft compared to $2-3/ft). However, the study team's estimate (based on DI prices) is consistent with installation labor estimates from RSMeans ($14/ft).[27] For perspective, at a $65/hr labor rate, the previous DEER estimates imply an installation rate of less than 2 minutes per linear foot of insulation, whereas the study team's estimate implies an installation rate of roughly 8 minutes per linear foot of insulation.

[27] The RSMeans estimate is based on the installation of closed cell foam insulation on SHW pipes, averaged across estimates for 0.5" to 1.5" pipes.

5

Discussion of Results

Having presented the final data sources and ex ante estimates of unit equipment prices and non-equipment installation costs for in-scope measures, this section presents a brief discussion of the overall results from the following perspectives:

- Mapping results to current DEER and IOU workpaper measure definitions
- Key differences from previous ex ante measure cost estimates
- Key sources of uncertainty

We discuss the overall set of results from each of these perspectives in the subsections below. We then close the section with a discussion of lessons learned from the data collection and modeling approaches used in the study and then reframe these lessons into a set of specific recommendations for future measure cost studies.

5.1 Mapping Results to DEER and Workpaper Measure Definitions

The results previously presented in Sections 3 and 4 were shown at the technology and sub-technology level, so as to facilitate detailed documentation of the data sources and methods used. However, for many in-scope deemed measures, that level of results reporting is more disaggregated than the technologies and measures defined in DEER and the IOU workpapers. For example, the results presented in Section 3.4 for linear fluorescent fixtures provide separate estimates for the average prices of linear fluorescent lamps and linear fluorescent luminaires (including ballasts). To estimate the total average cost of a complete fixture, it is necessary to add the estimates for the luminaire and the lamps. Similarly, some of the incremental equipment price examples shown in Section 3 do not account for the incremental installation costs for measures that involve cross technology baselines (e.g. HID fixtures to T5 fixtures, storage tank water heaters to tankless water heaters, etc).

The final step in mapping the results presented previously to current DEER and IOU workpaper definitions, therefore, is to appropriately combine the technology and sub-technology results for equipment prices and installation costs. Appendix F combines results from Sections 3 and 4 and provides the incremental and full measure costs (where applicable and available) for all in-scope deemed measures according to current DEER or IOU workpaper measure definitions as shown in the most recent version (1.0.4) of the Remote Ex Ante Database Interface (READI).[1,2] Note that in some cases, the measure definitions in READI do not include some key variables related to equipment size or performance. In these cases, the study team has augmented the READI measure definitions with additional explicit specifications (e.g. capacities, installation scenario) in order to allow prices and/or full installed costs to be estimated directly from the hedonic models developed for this study. These additional measure specifications are denoted in red text throughout Appendix F. Also note that there were a limited number of technologies for which the capacity units used in the equipment price and labor cost modeling were different from those specified in READI. Table 5-1 shows the conversion factors and assumptions used by the study team to derive equipment price and labor cost estimates that align to READI measure definitions for those technologies.

1 Note that Appendix F includes installation costs (and full measure costs) for several ROB measures to enable their treatment as ER measures.

2 Draft Combined DEER 2011 and DEER 2014 plus IOU Ex Ante for the 2013-14 Cycle.

Table 5-1: Capacity Conversions Applied to Match READI Capacity Units

Measure	MCS Capacity Units	READI Normalizing Units	Conversion
Whole House Fans	Equipment: CFM and # fans Labor: Unit	Unit	None – assumed CFM and # fans in measure definitions as follows: 2500 CFM, 1 fan, industrial grade 1600 CFM, 1 fan 2500 CFM, 1 fan 4500 CFM, 1 fan 1150 CFM, 2 fans
Direct Evaporative Coolers	Equipment: CFM Labor: CFM	tons	1170 CFM per ton*
Indirect Evaporative Coolers	Equipment: CFM Labor: CFM	tons	1170 CFM per ton
Tankless Gas Water Heaters	Equipment: MBH Labor: GPM	MBH	None – assumed GPM (for labor model) based on MBH as follows: 240 MBH, 8 GPM 175 MBH, 6 GPM 120 MBH, 4 GPM
Large Gas Storage Water Heaters	Equipment: MBH and gallons Labor: MBH	MBH	None – assumed gallon and MBH equivalency as follows: 75 gal, 125 MBH 80 gal, 175 MBH

* Workpapers specify 1,300 CFM as approximately equivalent to 1 cooling ton at 0.1" static pressure. Title 20 requires performance metrics for DEC to be specified at 0.3" static pressure. On average, it was found that the difference between CFM delivered at 0.1" static pressure and 0.3" static pressure was a factor of 0.9 (CFM@0.1"x0.9=CFM@0.3").

Finally, it should be noted that Appendix F does not include incremental and full measure cost estimates for all iterations of CFL lamp measures and linear fluorescent fixture measures shown in READI. For those measure groups, READI includes 110 CFL lamp measures and 180 linear fluorescent fixture measures, all of which vary only by the base case and measure case wattages. For the sake of brevity, results for a subset of those measure definitions are provided in Appendix F, which are intended to represent the most typical installations.[3] Note also that Appendix F does not include incremental and full measure cost estimates for all iterations of HVAC measures currently shown in READI. Specifically, Appendix F does not include estimates for measures that are no longer available in the market (e.g. reciprocating chillers for

[3] The study team can easily generate incremental cost estimates for any combination of base case and measure case wattages but chose not to show a large volume of somewhat redundant results in Appendix F.

HVAC, packaged HP above 20 tons, etc.) or measures whose defined capacities were outside of those for which the study team collected data (e.g. centrifugal chillers less than 300 tons).[4]

5.2 Key Differences from Previous Ex Ante Estimates

Below we highlight and summarize some of the key quantitative differences between the incremental measure cost results and previous estimates from DEER and the IOU workpapers. Generally, the results highlighted below are those with the largest differences from previous estimates. However, we also highlight the key results for residential and nonresidential lighting measures due to their continued prominence in the IOU program portfolios. The measure-specific results that are not summarized below are generally either not significantly different from previous estimates or have not been previously included in DEER.

While it was difficult within the scope of this study to completely decompose and attribute the source of differences between our estimates and previous DEER/workpaper estimates, the study team attempted to assess the main factors that contributed to those differences. For appliance measures, the differences appear to be almost entirely related to the use of much larger price samples in combination with hedonic models in order to remove the influence of non-efficiency features on estimates of incremental cost. For electronics, the differences also appear to result from the use of larger price samples and hedonic models but also recent market trends related to specifically to the widespread adoption of LCD technologies. For lighting measures, the differences appear to be less related to data sources and sample sizes and likely reflect the combined effect of differences in the hedonic model specifications and higher-level market trends specific to CFLs and linear fluorescent lighting.[5] For food service measures, the differences appear to be mostly related to higher-level market trends (including the significance of the used equipment in this particular sector) that have resulted in a very limited supply of non-Energy Star-compliant products.

For HVAC and water heating measures, it was more difficult to unpack the exact source(s) of the differences highlighted below. In these cases, there are clearly significant differences in data sources, sample sizes, and analysis methods, as well as some identifiable market trends, changes to industry standard practice, and interactions with air quality regulations. Within the scope of this study, however, it was not possible to assess the relative contributions of these factors to the overall differences between our incremental cost estimates and previous estimates from DEER and the IOU workpapers.

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[4] Estimates of the average costs for such "out of sample" technologies can certainly be produced using the price models developed for this study, but the associated estimates would be subject to significant bias.

[5] In principle, some of the higher-level market trends in lighting could be attributable to the incoming EISA standards, but the study team's price data set only included EISA-compliant lamps in the highest lumen output category (1490-2600 lumens, roughly equivalent to legacy 100 W incandescent lamps).

5.2.1 Appliances and Electronics

The study team found statistically significant but relatively low incremental costs for full-size, Energy Star-compliant refrigerators. These estimates range from $18 to $40 per unit, depending on total volume, door configuration, and availability of through-the-door ice. These incremental cost estimates are 60-80 percent lower than the current DEER estimates. Similarly, the study team also found statistically significant but relatively low incremental costs for top-loading, Energy Star-compliant clothes washers, ranging from $28 to $44 per unit, depending on capacity and efficiency level. These incremental cost estimates are 60-75 percent lower than the current DEER estimates. For front-loading clothes washers, the study team found much higher, statistically significant incremental costs ($108 to $221 per unit). However, it should be noted that the latter estimates mainly reflect the DEER baseline assumption (front-loading replacing top-loading), rather than a dramatic difference in the magnitude of the coefficient on the MEF variable between the front-loading and top-loading price models. In fact, the MEF coefficient in the front-loading model is slightly smaller than that in the top-loading model (28.9 vs. 38.9).

For televisions, the study team found very little consistent evidence of statistically significant incremental costs due to on-mode and sleep-mode power when examining results across twelve screen-size and backlighting technology-specific models (19", 22", 32", 40", 46", and 55" for LED- and CCFL-backlit products separately). In fact, the only consistent finding for televisions is a non-statistically significant, *negative* incremental cost, i.e. higher average prices for higher on-mode and sleep-mode power consumption. The current IOU workpapers for this measure assumed an incremental cost of $10-$60 per unit (depending on screen size) but is based on the estimated difference in average prices between CCFL- and LED-backlit units.

5.2.2 MSB Lighting

The study team estimated the average incremental cost for CFL A-lamp/twister lamps to be less than $2/lamp for lamps under 25 watts and over $4/lamp for higher-wattage lamps. These estimates represent a small decrease in the average incremental costs for these products compared to previous DEER estimates. For interior CFL reflectors and globes, the average incremental costs are estimated to be below $3/lamp, which represents a significant decrease from previous DEER estimates (>$8/lamp). For LEDs, the average incremental cost for all lamp shapes is still high relative to both incandescents and CFLs, ranging from $7/lamp for torpedoes to $24-$33/lamp for A-lamps and $40-50/lamp for reflectors.

5.2.3 Linear Fluorescent Lighting

The study team found statistically significant but relatively small incremental costs for 4' T8 lamps (28W compared to 32W baseline). These incremental cost estimates ($1.22 to $2.02 per lamp, depending on rated life) represent a slight decrease from previous DEER estimates. For 4' T5 lamps (replacing 4' T8 lamps), the study team again found incremental costs ($7.36 per lamp) that are slightly lower than current DEER estimates when comparing only the average price of the respective lamps.

5.2.4 Residential HVAC

The study team found low but statistically significant incremental costs for high-efficiency RAC units – averaging roughly $16 per unit. These incremental cost estimates are comparatively much lower than the current IOU workpaper estimates ($50 per unit). The study team validated predicted prices from the RAC model against a large sample of C4A invoices, with predicted prices coming within 5 percent of actual prices on average. This level of out-of-sample validation gives the study team a high degree of confidence in the incremental cost estimate.

For furnaces, both predicted prices and incremental costs are fairly consistent with current IOU workpaper estimates for 90 and 92 AFUE units ($335-$380/unit). However, for lower AFUE units (81 AFUE), the study team's incremental cost estimates are much lower than IOU workpaper estimates ($80/unit vs. $300/unit), whereas for higher AFUE units (96 AFUE) the study team's incremental cost estimates are much higher ($900 vs. $500/unit). When benchmarked against a small sample of online distributor prices, the study team's predicted prices for lower AFUE units generally over-predicted actual prices by 5-10 percent but under-predicted actual prices for higher AFUE units by 20+ percent. From this perspective, the benchmarking exercise appears to reinforce that the differences with current IOU workpaper estimates are indeed valid.

For split-system DX, the study team's predicted prices are systematically lower compared to current and previous DEER estimates by 10-30 percent. Similarly for incremental costs, the study team's estimates for split-system DX are consistently lower than current DEER estimates by 10-30 percent.

The predicted price for ECM fan motors for residential HVAC systems is significantly higher than current IOU workpaper estimates ($352 vs. $198 for a 0.5 hp unit). It should be noted, however, that the IOU workpaper estimates were based on price quotes from one distributor (EFI) that no longer carries that line of ECM motors (Concept 3).

For duct testing and sealing, the study team's installation cost estimate is roughly twice that from DEER 2005 ($91/dwelling) but less than half of the DEER 2008 estimate ($441/dwelling). From these benchmarks alone, it is thus difficult to assess the validity of the study team's estimate based on a small sample of DI prices. Indeed, the study team's installation labor cost estimate ($181/dwelling) is only based on prices from two DI contractors. However, the IOUs provided additional price data from five other DI contractors for which only total labor plus materials prices were provided. Across the larger sample of seven DI contractors, the average total labor plus materials costs for this measure was $270/dwelling, which is very consistent with the total of the separate labor and materials cost averages from the two DI contractors that provided itemized prices ($252/dwelling).

5.2.5 Residential Water Heating

For storage water heaters, the study team's predicted prices and incremental cost estimates are consistently higher than current DEER estimates. While it is difficult determine exact the exact source of these differences, the fact that the study team's predicted prices (across a range of capacities and efficiencies) validate well against "out of sample" prices lends credence to the study team's estimates. However, the study team found that the availability of baseline efficiency units (generally EF=0.60 and below) from equipment distributors was remarkably low compared to higher efficiency units, and further investigation indicated that standard practice among contractors in California is to specify and install above-code gas storage water heaters, usually with an EF rating of 0.62. While this evidence of market transformation is admittedly anecdotal, the direct impact on the analysis is that the final price sample was skewed towards higher efficiency units.[6] The study team therefore has less confidence in the price model's predictive power for baseline efficiency units, compared to higher efficiency units.

5.2.6 Nonresidential HVAC

For small packaged DX (less than 5 tons), the study team's incremental cost estimates are in line with the DEER 2008 estimate. However, strict comparisons are difficult since only a broad capacity range is defined in DEER 2008 (less than 65 kbtuh) – which implies that the study team's estimated incremental cost is higher than previous DEER for 1-2 ton units but lower for 4-5 ton units. For small packaged HPs (less than 5 tons), the study team's predicted unit prices are consistent with those in DEER 2005, but incremental costs are roughly twice those estimated in DEER 2005.[7] For large packaged DX and HPs (greater than 5 tons), the study team's predicted unit prices validate well compared to artificial project bids developed by EMCOR but are systematically higher than previous DEER estimates, particularly for units 20 tons and over. Nonetheless, the study team's incremental cost estimates for large packaged DX are slightly lower than those from DEER 2008.[8]

For non-condensing SHW boilers, the study team's predicted prices and incremental cost estimates are largely consistent with previous DEER estimates.[9] One key exception, however, was that the study team found no statistically significant price differences related to atmospheric

6 Indeed, the mean EF rating in the final price sample for gas storage water heaters is 0.63.

7 Small packaged HPs were not included in the DEER 2008 update.

8 The study team's incremental cost estimates for large packaged HPs are not strictly comparable to those from DEER 2008, as both the baseline and measure efficiency levels have since changed, and incremental costs for current baseline-measure efficiency increments were not previously estimated.

9 No benchmark data was available from previous DEER, IOU workpapers, or RSMeans to validate the study team's predicted prices for condensing SHW boilers.

versus forced draft units, whereas previous DEER estimates showed significant price premiums for forced draft units on the order of 7-10 percent (for units larger than 1000 MBH).

Compared to DEER 2008, the study team's predicted unit prices (for fan VFDs) are much lower ($60-116/HP compared to $176/HP). However, strict comparisons are difficult since the study team estimated separate models for <10 HP units and 10+ HP units and also controlled for the (significant) price impacts of NEMA enclosure type and other product features not currently specified in DEER and the IOU workpapers.

For indirect evaporative coolers, the study team's predicted unit prices are significantly higher than all previous DEER estimates (2001, 2005, and 2008). It should be noted, however, that these comparisons are based on rough CFM-to-tons-cooling conversions, since previous DEER estimates were all expressed on a per-ton cooling basis.[10] Additionally, the study team's model results are consistent with the raw unit price data, which were thoroughly vetted with EMCOR.

5.2.7 Nonresidential Water Heating

For large storage gas water heaters, the study team's predicted unit prices and incremental costs compare well to those from DEER 2008. It should be noted, however, that the study team's predicted unit prices are systematically higher compared to a small sample of online retailer price lookups, particularly for baseline efficiency units.

5.2.8 Food Service

The study team's incremental equipment cost estimate for electric fryers is $1,837/unit, which is nearly 5 times lower than the DEER 2005 estimate (assuming average production capacity of 70 lbs/hr for 14" vats). However, this estimate is also roughly 2.5 times higher than the current IOU workpaper estimate, which appears to be based on a slightly larger confidential price dataset. Similarly for gas fryers, the study team's incremental equipment cost estimate is $2,119/unit (assuming 70 lbs/hr production capacity), which is significantly lower than the DEER 2005 estimate but also significantly higher than the current IOU workpaper estimate. For full-size convection ovens, the study team's estimate of incremental equipment costs are negative, whereas current IOU workpaper estimates are positive on the order of $1,000/unit (electric and gas).

The study team believes that these results primarily reflect the paucity of matched pairs that could be assembled for this analysis, rather than robust analytic findings. However, it is also clear that a significant share of manufacturers have discontinued production of non-qualified

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[10] Strictly speaking, converting CFM to tons cooling equivalent requires knowing the temperature differential between indoor and outdoor air, as well as the technical specifications of the HVAC systems. Actual CFL to tons cooling ratios can vary by ±30 percent or more.

fryers and convection ovens, which vastly limits the number of non-qualified new units available in the market.

5.3 Discussion of Uncertainty

As a byproduct of using hedonic price modeling to estimate incremental costs for the majority of the in-scope deemed measures, the study team was also able to develop quantitative estimates of the uncertainty associated with the predicted average price (full or incremental) of energy-efficient products in the form of standard errors (for each estimated coefficient) and mean absolute errors (MAE) (for each model specification as a whole).[11] Strictly speaking, however, the standard errors and MAE values calculated by the study team only provide a quantitative measure of the relative error of the predicted values compared to the sample. If a given price sample is representative of the population, then the standard errors and MAE estimated from the sample should also reflect the relative error of the predicted values compared to the population. In this sense, the representativeness of the uncertainty estimates is thus dependent on the representativeness of the sample.

For this study, there were seven measure groups whose price samples were large and arguably highly representative of their respective populations in California – refrigerators, clothes washers, RAC, televisions, incandescent lamps, CFL lamps, and LED lamps. The final price data set for linear fluorescent lamps was also large and (as described in Section 3.4.1) was explicitly designed to have brand shares and lamp length shares similar to those observed in the onsite surveys conducted for WO29. For other measure groups, however, even in cases where the price samples were large (e.g. 176 for furnaces, 184 for fan VFDs, 778 for DCV, 108 for chillers) and/or the level of model fit was quite high (e.g. $R^2>0.7$), it is difficult to directly establish the representativeness of the price samples. As such, the standard errors and MAE values calculated for these other measure groups should only be interpreted as the relative error of the predicted values compared to those particular price samples. Indeed, this inherent difficulty in assessing the representativeness of many of our price samples was the main reason that the study team chose to supplement these standard quantitative estimates of uncertainty with systematic validation and benchmarking of predicted price estimates against out-of-sample prices and labor costs.

Another key source of uncertainty that is not captured by standard errors or MAE (even with representative sample frames) is the final price markup for equipment sold to final consumers via third party contractors (e.g. HVAC and water heating). While the study team attempted to estimate average markups for each such measure from a variety of sources (artificial project bids, RSMeans, etc.), actual markups can vary widely over time and across distributors and

[11] See Section 2.5.5 for more detailed discussion of standard errors and MAE.

contractors. Actual markups depend on a host of dynamic and diffuse factors such as individual contractor-distributor-manufacturer relationships, individual contractor or distributor product inventories, the number and size of competing firms, and macroeconomic conditions.

Finally, variability in non-equipment installation costs is also a major source of uncertainty for many in-scope deemed measures, particularly large capital equipment. In those cases, the study team attempted to bound this variability by developing installation cost estimates for a range of distinct installation scenarios and breaking out variable installation costs from fixed installation costs. However, the sample sizes associated with the related artificial bids were limited and do not allow for statistical estimates of the uncertainty of the average labor costs *within* each installation scenario.

5.4 Lessons Learned

By design, the study team attempted to use price data collection at the distributor level and hedonic price modeling on a wider scale than previously attempted in California. While the study team feels that the overall effort was successful and yielded many important benefits to the CPUC and the IOUs, this data development and analysis approach was also challenging to apply on such a broad scale. Below we summarize the main challenges encountered by the study team over the course of the study.

Developing consistent and complete product attributes for each price record is time-consuming and expensive. Specifying the number of variables needed to develop well-performing hedonic price models often requires acquiring and developing data from product-specific cut sheets. The process of assembling these cut sheets and extracting the required product data can be very time-consuming and one of the most expensive steps in the overall data development process. Additionally, this step requires analysts to be well-versed in the various performance/capacity metrics and product features relevant to hedonic price modeling and incremental measure cost estimation for a wide variety of different technologies and products.

The sole exception to this was the POS data sets acquired by the study team, which included dozens of product characteristics for each price record. Indeed, a major aspect of the value proposition made by vendors of POS data is that such product characteristics are included on a comprehensive basis.

Assessing the relative market position of distributors is difficult and inexact. Distributor pricing practices can vary widely for identical products. As with contractor markups to final customers, distributor markups and bulk volume discounts to contractors depend on a host of dynamic factors such as purchase volume, individual contractor-distributor relationships, individual distributor product inventories, and the number and size of competing distributors.

In order to reduce this variability, the study team attempted to assess the relative market position of each distributor that provided price quotes for this study in order to identify low-volume and/or niche suppliers whose prices reflect higher-than-average markups. This was done by comparing advertised prices for the most common products (e.g. 13 W CFLs, 4' T8s, 40-gallon 0.62 EF storage water heaters, etc.) and assessing the breadth of the product catalogues – where high prices for commodity goods and/or limited product offerings served as the primary indicators of relative market position. Admittedly, this method is cursory. However, direct quantitative measures of supplier size in terms of shipment volumes are simply not readily available. It is possible to use proxy measures for shipment volumes like annual revenues (which are available from services such as Dun & Bradstreet and InfoUSA), but such data are also expensive and even then, are still only available at the firm-level rather than the technology-level.

In summary, the methods that can be readily used to assess the relative market positions of individual distributors (to reduce the related variability in a sample of distributor prices) are inexact at best. This issue is most significant when developing price samples for commodity goods such as MSB lamps and linear fluorescent lamps. Conversely, this issue is of much lesser significance for smaller technology markets with more limited number of manufacturers and distributors (e.g. large capital equipment).

Developing market average measure costs from hedonic models often requires sales weights. The model specifications developed by the study team often included multiple variables (e.g. brand, color) that are currently not explicitly included in DEER or IOU workpaper measure definitions. In these cases, it was necessary to apply weights to all such variables in order to "roll up" the detailed modeling results into market average prices at the DEER/IOU workpaper measure definition "level". Specifically, 62 of the 77 hedonic models developed by the study team were specified such that sales weights were required to roll up the model results into DEER-equivalent market averages. Ideally, the data used to develop these roll-up weights should be recent market shares or volume shares based on large, representative samples of recent purchases in the California market.

For this study, the study team was fortunate to have direct access to the most recent market share data available in California in the form of POS data purchases and onsite surveys conducted for other concurrent EM&V studies. These market data allowed the study team to develop well-grounded sales weights for 49 of the 62 hedonic models that required them. However, no such market data were available for 13 hedonic models with more detailed specifications than current DEER/IOU workpaper definitions.[12] For these models, the study team defaulted to using roll-up

[12] These models included: residential HVAC fan motors, DCV, direct evaporative coolers (non-residential), waterside economizers, batt insulation, general service linear fluorescent fixtures (recessed w/cover, recessed no cover, suspended, surface-mounted), high bay linear fluorescent fixtures, photocells (sensor only).

weights based on the distribution of the given feature within the price sample, using the strong assumption that those price samples were representative of the total market.

While the study team was in a fortunate position for this study, it may or may not always be the case that such a substantial amount of recent market data will be readily available going forward. To the extent that future cost studies build upon the hedonic modeling developed by the study team, developing the sales weights necessary to roll up detailed hedonic model results into DEER-equivalent market averages will remain a significant and continual challenge.

Hedonic models cannot be used or offer no value for certain types of measures. While hedonic models offer many important advantages and benefits for estimating incremental costs of high-efficiency technologies, there are a significant subset of deemed measures for which hedonic models cannot be applied. These types of measures include primarily: 1) maintenance interventions such as duct testing and sealing, refrigerant charging, and condenser/evaporator coil cleaning, where final prices to customers are largely determined by labor costs rather than materials costs; and 2) commercial and industrial refrigeration measures that are more akin to projects and involve multiple technologies and specialized labor.

Additionally, there are a subset of deemed measures whose prices are only influenced by one or two explicit factors (e.g. infrared film, thermal curtains, pool covers). For these types of measures, hedonic models do not offer significant additional value compared to simpler analytic methods such as matched-pair averages.

Contractors need to be properly compensated in order to respond to artificial project bid solicitations. Artificial project bids are an appropriate method to estimate how non-equipment installation costs vary according to specific installation site and access conditions and to delineate between fixed and variable non-equipment installation costs, given that a sufficient number of contractors provide complete responses. However, contractors are not inclined to respond to such research requests voluntarily. Indeed, the study team offered compensation to all of the contractors that participated in this study, and even then faced some difficulty soliciting a sufficient number of responses. An ongoing challenge will be to determine the level of compensation and a compensation process that ensure a sufficient number of quality responses but balance those costs with competing research needs.

5.5 Recommendations and Future Work

In the final subsection below, we reframe the main lessons learned from the study into a set of specific recommendations for future work. First, we present a targeted set of technology-specific research recommendations that are designed to address key issues that could not be resolved or addressed within the scope of this study. We then present a strategic set of specific methodological and process-related recommendations for future measure cost studies in California.

5.5.1 Technology-specific Recommendations

Below we provide research recommendations that are focused on technology-specific issues that go beyond general recommendations for collecting larger price datasets, assembling representative sample frames, and collecting more market share data. In other words, the recommendations presented below are more topical in nature, rather than related to overall research design, data collection, or analysis approaches. These particular issues were identified by the study team through the course of the study but could not be resolved or addressed within the scope of the project.

Further Explore How Installation Costs Scale with Increasing Capacities for Large Capital Equipment

Large capital equipment such as packaged DX, chillers, and boilers can span a very wide range of capacities (in terms of cooling or heating capacity) and equipment sizes (in terms of weight and physical dimensions). Chillers, for example, can be sized as small as 50 tons or as large as 1,500 tons – which translates to units that range from roughly 300 ft^3 and 2,000 lbs to 1,500 ft^3 and 50,000 lbs. From the artificial bids developed for this study and the study team's discussions with contractors, there is anecdotal evidence that installation costs for large capital equipment follow a "tiered" pattern with increases in capacity rather than a linear pattern (i.e. relatively constant across specific capacity ranges and then increase in a step-wise manner once a capacity threshold is reached). From discussions with contractors, this tiered pattern is related to the weight and dimensions of the unit and the associated moving equipment, rigging, and logistics required to remove existing units and place new units.

The study team was able to observe indications of this pattern within the small sample of artificial bids and validation data assembled for this study, but those data only covered a limited number and range of capacities for large capital equipment – 40-70 tons for packaged DX (2 points), 100-300 tons for chillers (3 points), and 200-3000 MBTU for boilers (3 points) – which was not enough data to reasonably validate or estimate the relationship between unit size and installation costs at higher capacities. Going forward, therefore, the study team recommends that this relationship be explored more explicitly. This could be accomplished in a variety of ways, from assembling and examining actual cost records from similar past projects (likely from calculated incentive programs) to expanding an artificial bid exercise to include a larger number of packaged DX, chillers, and boiler projects that are designed to explicitly test the existence/validity of the step-wise relationship. The relevance of this future work is tied directly to enabling more accurate and diligent ex ante review of incentive applications for these types of very large capital equipment replacement projects, for which both the ex ante savings claims and the associated incentive payments are large.

Perform Dedicated Research on Network Power Management Software

As discussed in Section 3.9, the study team faced several fundamental analytic issues when attempting to estimate the incremental costs associated with acquiring and installing network power management software. These issues included: 1) the availability of both freeware and commercial software; 2) the practice of bundling features not related to power management functionality; and 3) the difficulty in delineating differences in power management strategies, their relative effectiveness, and their respective impact on product price. One of the fundamental barriers to addressing these issues is that detailed information on product-specific functionality and power management strategies were largely limited to interpreting product marketing literature. It was therefore difficult if not impossible to verify claims made by developers (either over the phone or in their product literature).

Given this measure's expected role in future IOU portfolios, the study team recommends conducting dedicated research to tackle some or all of the issues above in more depth than was possible within the scope of this study. Specifically, this research should acquire some or all of the currently qualified products and either examine the source code or otherwise test each product to systematically identify and categorize the specific power management strategies and non-power management features included with each product. The research should also assess the types of products that customers in California have adopted to date, either within IOU programs or from a general population perspective, in order to establish basic market shares of freeware vs. commercial software, power management-only vs. multi-purpose functionality, and power management strategies (e.g. direct implementation of sleep settings and on-off schedules vs. client-specific energy consumption dashboards and learning algorithms). This latter type of research could accomplished through surveys of either the general eligible customer population or past program participants, perhaps in combination with an analysis of related program invoice data.

Incorporate LER ratings into Cost Analysis of Nonresidential Lighting Fixtures

The current energy performance metric used in DEER and the IOU workpapers for nonresidential lighting fixtures is fixture watts. However, there is momentum within the lighting industry to move to a different energy performance metric, luminaire efficacy rating (LER), which measures performance from a "useful lumens delivered per input watt" perspective.[13] Voluntary testing protocols to support this metric were developed by NEMA in 2001, and LER is

[13] LER is defined as LER (lumens/watt) = [luminaire efficiency (EFF) x total lamp lumens x ballast factor (if lamps are ballasted)] / total luminaire input watts, where EFF = ratio of total zonal lumens to total rated lamp lumens. See http://energy.gov/eere/femp/articles/covered-product-category-fluorescent-luminaires.

used as a qualifying metric for the USDOE's Federal Energy Management Program (FEMP). The LER metric allows the influence of the luminaire design to be integrated with the efficiency of the light source itself (LED, HID, incandescent, or fluorescent) to provide better direct comparisons of the overall efficiency of lighting systems, compared to using only total fixture wattages or generalized estimates of "lumen equivalencies".

For this study, the study team attempted to develop LER values for each record in our price sample for linear fluorescent fixtures (to include as a variable in the hedonic price modeling). However, LER values and/or the components needed to calculate LER (namely luminaire efficiency) are still not yet universally available in product cut sheets or the USDOE's product compliance databases. As such, the study team could not develop LER values for even a majority of records in our price sample and did not include LER as a variable in our price modeling for linear fluorescent fixtures. As a result, the study team suspects that the estimated coefficients for the brand variables in our price models for fixtures (see Table 3-14) are also capturing price impacts related to high-performance luminaire designs (and materials).

Given that LED lamp and luminaire prices, while declining, are still significantly higher than those for HID and fluorescent systems and that future gains in the efficacy of HID and fluorescent lamps are expected to be modest at best, the study team believes that the next generation of nonresidential lighting programs will necessarily have to focus to some extent on high-performance luminaire designs. To do enable this, the study team recommends that, as one of the first steps, LER be explicitly incorporated into future analyses of measure costs and savings for both linear fluorescent and HID fixtures, as well as potentially LED fixtures.

5.5.2 Methodological and Process-related Recommendations

Below we present specific methodological and process-related recommendations for future measure cost studies in California. These strategic recommendations attempt to build upon the methodological and data collection advances made in this study and address the main challenges faced by the study team.

Perform Regular, Targeted Market Assessments to Inform Cost Data Collection

Measure cost studies such as this have tended to be very "lumpy" in nature, i.e. large, expensive, and time-consuming efforts. Indeed, a consistent recommendation in previous cost studies conducted in California and elsewhere has been to conduct these studies more often and in a more targeted way to reduce this lumpiness. While the study team agrees with that general recommendation, there is little evidence demonstrating that those previous recommendations have resulted in measure cost studies that are any less lumpy than previously. From the validation and benchmarking conducted for this study, it is also clear that while some ex ante cost estimates have changed dramatically (demonstrating the need for more frequent updates to measure cost estimates), a significant share have remained fairly constant compared to previous estimates.

Therefore, rather than repeating previous recommendations to conduct these studies more often in an effort to make them less lumpy, the study team recommends performing regular, targeted market assessments to inform efforts to collect and update measure cost estimates. This recommendation is qualitatively different in that it is geared towards answering first order questions such as "which of the existing estimates are still valid?" and "which technology/service markets have changed/are changing significantly and which have not?" Additionally, given the CPUC's renewed emphasis on market transformation, such market assessments could be scoped to also address a wider range of market transformation research issues, thereby increasing their value beyond just cost-related research.

As noted throughout Section 3, through the course of collecting and developing certain equipment price samples, the study team essentially conducted several small-scale market assessments as a part of this study. While these efforts clearly revealed some important findings (as highlighted throughout Section 3), the process of conducting such research concurrently with a large-scale data collection effort was clearly sub-optimal. The study team believes that conducting such targeted market assessments on a regular basis (e.g. bi-annually) would serve as a direct way to reduce the scope, cost, and calendar of future measure cost studies while potentially increasing their long-term value.

Specifically, such targeted, regular market assessments would serve to: 1) identify which existing estimates are still valid, 2) identify changes in industry standard practices that impact incremental costs, 3) identify interactions with non-energy codes that influence baselines and product availability, 4) identify and strategically target specific market actors for data collection, 5) identify key product features and/or performance metrics (particularly emerging ones) that should be included in hedonic models and measure definitions.[14] Each of the benefits listed above would directly enable the scope, budgets, and research activities of future measure cost studies to be more explicitly targeted and optimized than what was possible for this study and previous studies.

Integrate Make/Model and Installation Cost Data into Program Tracking for Downstream Deemed Measures

Historically, program tracking data has been under-leveraged as a raw data resource for measure cost studies. This has primarily been due to a lack of corresponding price data on baseline equipment and concerns related to limiting the resulting price sample to only program-qualifying

[14] Specific examples of emerging product features relevant to future program offerings are controllable ballasts that use the Digital Addressable Lighting Interface (DALI) protocol and LER ratings for luminaires.

equipment (as opposed to all high-efficiency equipment on the market). 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 in terms of distributions by size, efficiency, and other relevant features.

The study team believes that, with only two incremental changes, program tracking data could become an extremely important, low-cost, continual source of price and volume data to inform measure cost studies and market share tracking. First, we recommend that all of the information currently solicited on downstream rebate forms (including the make/model information for the purchased equipment) be included as fields in the IOUs' program tracking databases. To be clear, it is the study team's understanding that the IOUs already record the make/model information from the rebate forms for some programs into central databases (e.g. for the Quality Installation program). Our recommendation is to simply carry that information forward into program tracking databases for all downstream deemed rebate programs, since that information is already solicited on all respective rebate forms. We believe that including such information in program tracking databases would provide an extremely useful, albeit imperfect, primary data source for unit equipment prices since it would then be possible to append equipment size, efficiency, and other feature information to each record. Granted, such program tracking data would still only include in-program equipment and prices for baseline equipment would still need to be collected through separate efforts. Nonetheless, this would provide a comprehensive, low-cost, and valuable source of unit price data for in-program products.

Integrating make/model information into program tracking is even more valuable when considered as comprehensive data source for developing sales weights and market shares (by brand, feature type, efficiency level, etc.) to support hedonic modeling and market share tracking. As noted in Section 5.4, while the study team was in a fortunate position to have direct access to recent market share data for this study, it may not always be the case that such a substantial amount of recent market data (particularly onsite survey data) will be readily available going forward. Integrating make/model information into program tracking represents a lower cost, direct, and timely method to develop and monitor market shares. This information could support on-going assessments of incremental measure costs, market share tracking, and progress towards market transformation goals.

Second, we recommend that third-party installation costs be explicitly included on rebate forms (where relevant) and integrated into program tracking as recommended above. Reporting installation costs is currently not a requirement for claiming downstream deemed rebates, which is logical given that most deemed rebates are designed to only pay incentives to cover a portion of incremental equipment costs. However, if installation costs were included as a reporting requirement (as information-only, as opposed to being tied to the incentive quantity) and that information were integrated into program tracking data, the resulting dataset could serve as a comprehensive, low-cost source of actual installation cost data. Importantly, the "in-program" bias noted above for equipment prices assembled from tracking data would not apply in the case of installation cost data, since the research conducted for this study has shown that equipment efficiency does not impact installation costs for most types of equipment. In other words, the installation costs derived from program-only equipment invoices would be equally applicable to baseline and non-program equipment.

Consider Standardizing Data Development and Analysis Procedures for Measure Cost Estimation

As we have noted throughout this report, a significant portion of the results from this study are not strictly comparable to previous estimates due to differences in the data sources and/or analytic methods used (as opposed to changes in code or standard practice). This inconsistency in the data sources and methods used greatly inhibits the ability to conduct meaningful longitudinal analysis of changes in measure costs over time. Given the CPUC's renewed emphasis on market transformation, we feel it is critical to explicitly establish the capacity with which to monitor and evaluate progress towards market transformation goals. From this perspective, the study team strongly recommends that the CPUC consider standardizing at least parts of data development and modeling used in measure cost studies going forward in order to enable more meaningful longitudinal analysis and tracking of measure costs in California.

Below we provide four specific recommendations for standardizing parts of the data development and modeling used for measure cost studies in California going forward.

Continue Use of Hedonic Price Modeling as Primary Analytic Framework

The study team believes that while there are significant challenges associated with developing and estimating hedonic price models at the scale and breadth attempted in this study, the benefits from using this approach to the CPUC, the IOUs, and the energy efficiency community at large are substantial. First and foremost, hedonic price models are inherently flexible in their application and can be used to predict and estimate average measure costs across a wide range of measure definitions and quickly update those cost estimates when measure definitions change. Second, hedonic model specifications are easily documented, which allows results to be easily reproduced and made transparent. This transparency and reproducibility in turn enables results to be more easily and directly compared across studies and over time. Third, hedonic models provide a framework for quantifying the uncertainty associated with incremental cost estimates and, as datasets expand over time, explicitly integrating time trend analysis.

As noted in Section 5.4, it should be understood that hedonic modeling is not well-suited to estimate the incremental costs of maintenance measures (e.g. duct testing and sealing) or measures that involve multiple technologies and specialized labor (e.g. commercial refrigeration). Additionally, there are some measures for which the benefits of hedonic models are more marginal due to the fact that prices for those products are only influenced by one or two factors (e.g. infrared film). However, for the vast majority of deemed measures currently included in the IOU program portfolios, the study team believes that the benefits of using a hedonic modeling approach to estimate incremental costs far outweigh the challenges.

Systematic Use of Product Compliance Databases

Wherever possible, the study team recommends using the product compliance databases developed and maintained by the CEC, USDOE, USEPA, and AHRI to merge key product characteristics onto each price record. These databases have several key features that make them extremely valuable resources in the context of this study and measure cost studies in general. First, they are publically available and updated regularly. Second, they tend to cover both highly-efficient technologies as well as standard-efficiency baseline technologies. Third, and perhaps most importantly, the capacity ratings and energy performance metrics are based on common testing procedures and are therefore directly comparable and reduce or eliminate systematic bias related to manufacturer claims. This latter feature is critical for technologies that either have complex or multiple energy performance metrics (e.g. SEER, EER, COP, EF, combustion efficiency, thermal efficiency) or whose capacities can be determined in a number of different ways (e.g. CFM vs. cooling tons for direct evaporative coolers).

For products and technologies not covered by those databases, the study team recommends that the CPUC consider building and maintaining an analogous database of product characteristics. For certain technologies, the compilation and cataloguing of product characteristics already occurs regularly as a central part of EM&V studies (e.g. WO29, WO24). These efforts are currently ad hoc, but one could easily envision combining those existing resources into a central database that would serve as a shared resource between the CPUC, the IOUs, and other stakeholders.

Systematically using such centralized databases of product characteristics would produce multiple benefits to the CPUC and the IOUs. The most obvious benefit is that it would ensure consistency in the way that product features and performance are characterized. This in turn would reduce systematic bias in the analysis of both incremental measure cost and energy savings. Perhaps most importantly, it would serve to reduce the data development costs associated with not only measure cost studies but also market share tracking studies and certain types of EM&V studies.

It should be understood that the product compliance databases listed above were sometimes either incomplete or did not contain any product characteristics outside of basic capacity and energy performance criteria. In this sense, should the CPUC pursue this recommendation, the study team would encourage the CPUC to work with those associated agencies to gradually expand the number of fields available for each technology, with a long-term objective of having all of the product characteristics necessary for incremental cost analysis systematically included (and regularly updated) in those databases.

Expanded and Regular Use of POS Data

Until alternative data sources can be identified and developed, the study team recommends that the CPUC acquire and leverage POS data on a regular basis to support measure cost studies and market share tracking studies. POS data are a natural source for feeding and developing hedonic price models. For mass market measures, large samples of POS data for some measures can be readily purchased from third-party marketing firms, which make it possible to conduct regular, targeted updates for those measures as often as every quarter. While the cost of such data sets can be significant and lower-cost alternatives to POS should be explored, we believe that their near-term value to the analysis and tracking of incremental measure costs and market shares is clear. Our direct experience with such marketing firms also suggests that if there were larger demand for such POS data (in particular from an energy efficiency analysis point of view), that most if not all marketing firms would make efforts to increase the depth and breadth of their POS data offerings to meet that demand.

Expanded and Consistent Use of Artificial Project Bids

From the experiences gained in this study, the study team believes that artificial project bids are an appropriate and effective method to estimate how non-equipment installation costs vary according to specific installation sites and access conditions and to delineate between fixed and variable non-equipment installation costs, particularly for large capital equipment. As such, the study team recommends standardizing and expanding the use of artificial bids as a central cost data collection and development approach for large capital equipment going forward.

Besides supporting the wider development of ex ante installation costs, artificial project bids could also be used as a way to directly explore the relationship between installation costs and unit capacity for very large equipment (see discussion in Section 5.5.1). Artificial project bid efforts could be also be conducted on a more frequent, targeted basis as a low-cost method to validate current estimates of capital equipment prices and installation costs, akin to the targeted market assessments recommended earlier in this subsection. Finally, and perhaps most importantly, systematic use of artificial project bids would also enable longitudinal analysis of equipment prices and installation costs for capital equipment, if repeated on a regular basis with consistent bid structures and contents.

Appendix A

Commission Staff Memorandum – Final In-scope Measure List

In 2012, Itron ranked all DEER and non-DEER deemed measures to prioritize measures for the incremental measure cost study update. Energy Division asked that Itron refine the priorities based upon contribution to 2013-14 incentive, quality of current estimate, and future codes and standards update. Utilizing the 2013-14 incentive contribution as a metric for prioritization allowed measures to be ranked based upon the amount of ratepayer money spent on promoting the particular measure.

A rank score of 3.5 and above was utilized as a threshold point to identify priority measures. Table 1 summarizes the final scope of measures included Please note that there are measures ranked below 3.5 (e.g., residential LEDs, building shell measures) that are included within the scope of the final priority measures. Energy Division felt that these measures should be included within the scope of this cost study update to reflect measures anticipated to increase in importance going forward (e.g., in whole building projects), therefore updating their cost data at this time is prioritized.

Table 1: Deemed Measures within Final MCS Scope

Sector	End Use	Tech Group	Measure Group	Total Rank ('13-'14)
C&I	HVAC	DX	Packaged DX	**4.8**
Residential	Electronics	Other plug load	Televisions	**4.5**
Residential	Lighting	Exterior lighting	HID	**4.3**
C&I	Lighting	Interior lighting	LF lamps	**4.3**
C&I	Lighting	Interior lighting	LF fixtures	**4.3**
C&I	Lighting	Interior lighting	Electronic ballasts	**4.3**
C&I	Lighting	Interior lighting	LED fixtures	**4.3**
C&I	HVAC	DX	Split HPs	**4.3**
C&I	HVAC	DX	Packaged HPs	**4.3**
Residential	Lighting	Interior lighting	CFL lamps	**4.0**
Residential	Appliances	Cold storage	Refrig recycling	**4.0**
Residential	HVAC	Air distribution	Duct test & seal	**4.0**
C&I	Lighting	Controls	Occupancy sensors	**4.0**
C&I	HVAC	DX	Split DX	**4.0**
C&I	HVAC	DX	RCA	**4.0**
Residential	Building Shell	Envelope & Air Sealing	Envelope & Air Sealing	**4.0**
Residential	Appliances	Cold storage	Refrigerators	**3.8**
Residential	HVAC	DX	Room AC	**3.8**
C&I	HVAC	DX	PTACs	**3.8**
Residential	Appliances	Laundry	Clothes washers	**3.5**
Residential	Appliances	Cold storage	Freezer recycling	**3.5**

Sector	End Use	Tech Group	Measure Group	Total Rank ('13-'14)
Residential	Electronics	Office	PC power management	**3.5**
Residential	HVAC	DX	Split CACs	**3.5**
Residential	HVAC	DX	RCA	**3.5**
Residential	HVAC	Evaporative cooling	Evaporative coolers	**3.5**
Residential	HVAC	Air distribution	Fan motors	**3.5**
Residential	Water Heating	Water heaters	Storage WHs	**3.5**
Residential	Water Heating	Water heaters	Tankless WHs	**3.5**
Residential	Water Heating	Water heaters	Heat Pump WHs	**3.5**
C&I	Refrigeration	Controls	Evaporator fan controls	**3.5**
C&I	Refrigeration	Controls	Remote refrigeration system controls	**3.5**
C&I	Lighting	Interior lighting	HID fixtures - general service	**3.5**
C&I	Lighting	Interior lighting	HID fixtures - high bay	**3.5**
C&I	Lighting	Delamping	Delamping	**3.5**
C&I	HVAC	DX	Coil cleaning	**3.5**
C&I	HVAC	Evaporative cooling	Indirect evaporative coolers	**3.5**
C&I	HVAC	Chillers	Chillers	**3.5**
C&I	HVAC	Heat rejection	Economizers	**3.5**
C&I	HVAC	Air distribution	Fan motors and VSDs	**3.5**
C&I	HVAC	Air distribution	DCV	**3.5**
C&I	HVAC	Space heating	Steam boilers	**3.5**
C&I	Pool	Pump	Pool pumps	**3.5**
C&I	Pool	Pool	Pool cover	**3.5**
C&I	Building Shell	Fenestration	Heat curtains	**3.5**
C&I	Building Shell	Fenestration	Reflective film	**3.5**
C&I	Water Heating	Liquid circulation	Demand control recirc pumps	**3.5**
C&I	Water Heating	Liquid circulation	Lowflow showerheads	**3.5**
C&I	Process	WH	Process boilers	**3.5**
C&I	Irrigation	Liquid circulation	Sprinkler	**3.5**
C&I	Refrigeration	Infiltration reduction	Auto-closers	**3.5**
C&I	Refrigeration	Cold storage	Display cases	**3.5**
C&I	Refrigeration	Remote refrigeration	Evaporator fan motors	**3.5**
Residential	Lighting	Interior lighting	LED	**3.3**
C&I	Building Shell	Fenestration	Low SHGC windows	**3.3**
Residential	HVAC	Space heating	Furnaces	**3.3**
Residential	HVAC	Space heating	Gas boiler	**3.0**
Residential	HVAC	Air distribution	Whole house fans	**3.0**
Residential	Building Shell	Insulation	Batt insulation	**2.8**

Sector	End Use	Tech Group	Measure Group	Total Rank ('13-'14)
Residential	Building Shell	Insulation	Blow-in insulation	**2.8**
Residential	Building Shell	Windows	Windows	**2.5**
Residential	Water Heating	HW distribution	Pipe insulation	**2.5**
Residential	HVAC	DX	Split HPs	**2.0**
Residential	HVAC	Air distribution	Fan VSDs	**2.0**

Table 2 below summarizes the list of measures that were considered for inclusion within this Measure Cost Study update, but that were ultimately not included within the final scope due to a relatively low ranking (i.e., less than 3.5). Please note that there are measures that ranked 3.5 or above that were excluded from the scope of final priority measures due to either an overabundance of research that has already been undertaken (e.g., C&I CFL lamps), or ambiguity in the measure definition (e.g., HVAC controller, BMS programming).

Table 2: Deemed Measures Excluded from Final MCS Scope

Sector	End Use	Tech Group	Measure Group	Total Rank ('13-'14)
Residential	Electronics	Other plug load	Set top boxes	**4.0**
C&I	Lighting	Interior lighting	CFL lamps	**4.0**
Residential	Water Heating	Controls	Water heating controller	**3.5**
C&I	HVAC	Other controls	Programmable thermostats	**3.5**
C&I	HVAC	Other controls	HVAC controller	**3.5**
C&I	Water Heating	WH	Large storage WHs	**3.3**
C&I	Refrigeration	Infiltration reduction	Strip curtains	**3.3**
C&I	Refrigeration	Controls	Vending machine controls	**3.3**
C&I	Refrigeration	Controls	Anti-sweat heater controls	**3.3**
C&I	Food Service	Cooking	Rack ovens	**3.3**
C&I	Food Service	Controls	Exhaust hood controls	**3.3**
Residential	Lighting	Interior lighting	Other lighting	**3.0**
Residential	Lighting	Controls	Photocell	**3.0**
Residential	Electronics	Other plug load	Plug load sensors	**3.0**
Residential	HVAC	Air distribution	Air filter alarm controls	**3.0**
Residential	Water Heating	HW distribution	Faucet aerators	**3.0**
C&I	HVAC	Other controls	BMS programming	**3.0**
C&I	HVAC	Other controls	Timeclocks	**3.0**
C&I	Pool	Pump	Pool heaters	**3.0**
C&I	Building Shell	Insulation	Wall insulation	**3.0**
C&I	Water Heating	WH	Tankless WHs	**3.0**
C&I	Water Heating	Liquid circulation	Other controls	**3.0**
C&I	Water Heating	Liquid circulation	Faucet aerators	**3.0**
C&I	Process	WH	Boiler tune-up	**3.0**
C&I	Process	Liquid circulation	Pump VSD	**3.0**
C&I	Refrigeration	Infiltration reduction	Night covers	**3.0**
C&I	Refrigeration	Cold storage	Ice machines	**3.0**
C&I	Refrigeration	Cold storage	Packaged (reach-in) refrigerators	**3.0**
C&I	Refrigeration	Remote refrigeration	Condensers	**3.0**
C&I	Food Service	Cooking	Convection ovens	**3.0**

Sector	End Use	Tech Group	Measure Group	Total Rank ('13-'14)
C&I	Food Service	Cooking	Fryers	**3.0**
C&I	HVAC	DX	PTHPs	**3.0**
Residential	HVAC	QI and QM	QI	**3.0**
C&I	Process	Air compressor	VFDs	**3.0**
Residential	Electronics	Office	Copier	**2.8**
Residential	Building Shell	Roof	Cool roof	**2.8**
C&I	Building Shell	Fenestration	IR film	**2.8**
C&I	Water Heating	WH	Small storage WHs	**2.8**
C&I	Process	Laundry	Ozone laundry	**2.8**
C&I	Food Service	Cooking	Combination ovens	**2.8**
C&I	Food Service	Cooking	Conveyor ovens	**2.8**
Residential	Lighting	Interior lighting	CFL fixtures	**2.5**
Residential	Lighting	Exterior lighting	CFL fixtures	**2.5**
Residential	Lighting	Controls	Occupancy sensors	**2.5**
Residential	Appliances	Laundry	Clothes dryers	**2.5**
Residential	Electronics	Office	Desktop computers	**2.5**
C&I	Lighting	Interior lighting	CFL fixtures	**2.5**
C&I	Lighting	Controls	Timeclocks	**2.5**
C&I	Lighting	Controls	Daylighting controls	**2.5**
C&I	HVAC	Liquid circulation	Pump motors and VSDs	**2.5**
C&I	HVAC	Air distribution	Air filters	**2.5**
C&I	Water Heating	WH	SHW boilers	**2.5**
C&I	Process	WH	Tank insulation	**2.5**
C&I	Irrigation	Liquid circulation	Drip irrigation	**2.5**
C&I	Refrigeration	Infiltration reduction	Display case doors	**2.5**
C&I	Refrigeration	Insulation	Suction line insulation	**2.5**
C&I	Refrigeration	Insulation	Glycol tank insulation	**2.5**
C&I	Refrigeration	Cold storage	Packaged (reach-in) freezers	**2.5**
C&I	Refrigeration	Remote refrigeration	Multiplex systems	**2.5**
C&I	Food Service	Cooking	Steamers	**2.5**
C&I	Food Service	Warming	Holding cabinets	**2.5**
C&I	Process	WH	Steam Trap	**2.3**
C&I	Food Service	Cooking	Griddles	**2.3**
Residential	Electronics	Office	Monitors	**2.0**
Residential	HVAC	DX	Hot-dry AC	**2.0**
C&I	HVAC	Heat rejection	Cooling towers	**2.0**
C&I	HVAC	Heat rejection	Cooling tower fans	**2.0**
C&I	HVAC	Heat recovery	Heat exchangers	**2.0**

Sector	End Use	Tech Group	Measure Group	Total Rank ('13-'14)
C&I	HVAC	Liquid circulation	Flow controls	**2.0**
C&I	HVAC	Air distribution	Flow controls	**2.0**
C&I	HVAC	Air distribution	Duct test & seal	**2.0**
C&I	HVAC	Air distribution	Duct insulation	**2.0**
C&I	HVAC	Space heating	Furnaces	**2.0**
C&I	Building Shell	Roof	Cool roof	**2.0**
C&I	Building Shell	Insulation	Floor insulation	**2.0**
C&I	Building Shell	Insulation	Ceiling/roof insulation	**2.0**
C&I	Water Heating	Liquid circulation	Pipe insulation	**2.0**
C&I	Process	Heat recovery	Milk pre-cooler	**2.0**
C&I	Refrigeration	Insulation	Wine tank insulation	**2.0**
C&I	Refrigeration	Remote refrigeration	Mechanical Subcooling	**2.0**
C&I	Refrigeration	Heat Recovery	Heat recovery	**2.0**
C&I	Food Service	Cooking	Stock pots	**2.0**
C&I	Refrigeration	Insulation	Glycol pipe insulation	**2.0**
C&I	HVAC	Air distribution	Ceiling fan	**2.0**
C&I	Process	Liquid circulation	Pumps	**2.0**
Residential	Appliances	Cold storage	Freezers	**1.8**
C&I	Building Shell	Fenestration	High transmittance glass	**1.8**
C&I	Refrigeration	Infiltration reduction	Door gaskets	**1.8**
C&I	Cross cutting	Motors	Motors	**1.8**
Residential	Lighting	Exterior lighting	CFL lamps	**1.5**
Residential	Appliances	Kitchen	Dishwashers	**1.5**
Residential	HVAC	Controls	Programmable thermostat	**1.5**
C&I	HVAC	DX	Room AC	**1.5**
C&I	HVAC	Space heating	Pipe insulation	**1.5**
C&I	Process	WH	Heat recovery	**1.0**
C&I	HVAC	QI and QM	QI	**1.0**

Appendix B

DNV-GL Technical Memoranda on Residential Lighting Data Collection and Analysis

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B.1 Technical Memorandum 1A: Shelf Survey Data Development

B.2 Technical Memorandum 2: Hedonic Regression Results

B.3 Technical Memorandum 3: Lamp Grouping, Lumen Ranges, and Wattage to Lumen Equivalencies

B.4 Interim Retail Channel Sales Weight

B.1 Technical Memorandum 1A: Shelf Survey Data Development

August 22, 2012

To	:	Katie Wu, Carmen Best, and Peter Lai Energy Division, California Public Utilities Commission
From	:	Andrew Stryker and Romilee Emerick DNV KEMA Energy & Sustainability
CC	:	Kathleen Gaffney and Fred Coito DNV KEMA Energy & Sustainability Mike Ting Itron Pete Jacobs ED Consultant Jeff Hirsch J.J. Hirsch & Associates
Subject	:	**Technical Memorandum 1A: Shelf Survey Data Development**

1. Overview

This technical memorandum is one of two that will describe the underlying data for developing residential lighting incremental measure costs. The focus of this memorandum is on the shelf survey data. The other data development memorandum will focus on the point of sale data, supplier interviews, and program tracking data that will form the basis for the retail channel sales weights. The shelf survey data form the basis for the hedonic pricing models that relate attributes of light lamps to the sale price. This memorandum describes the preparation an estimation dataset from the shelf survey, lists the quality control checks performed on the data, and shows preliminary relationships between prices and key attributes. The focus of this memorandum is medium screw base (MSB) lamps that are commonly part of the California investor owned utility (IOU) upstream lighting programs[1].

The organization of this memorandum is as follows. The following section gives an overview of the five different waves of shelf surveys conducted beginning in Fall 2008 and most recently in Fall 2011. Section 2 describes the data compilation stage in which the separate shelf survey datasets from five waves of shelf surveys were combined into one common dataset. Section 3 details which records fall within the scope of this study. Section 4 lists each of the steps and checks taken to prepare the combined dataset for further

[1] The three IOU territories are (1) Pacific Gas and Electric (PG&E), (2) Southern California Edison (SCE), and (3) San Diego Gas and Electric (SDG&E).

analysis. Section 5 shows preliminary descriptive relationships between key attributes and prices for specific types of light lamps. The last section describes the next steps for developing the hedonic pricing model. Appendix A describes the variables in the combined dataset.

2. Shelf Survey Data Collection

DNV KEMA's shelf surveys cover a variety of lamp types from different retail channels in IOU territories in California. There were important differences, however, in the data collected during each of the five collection periods, as summarized in Table 1. The table highlights only the differences that are relevant for the hedonic pricing model. See Appendix A for a summary of the attributes collected in each survey wave and a description of how the attributes were mapped into a unified table structure.

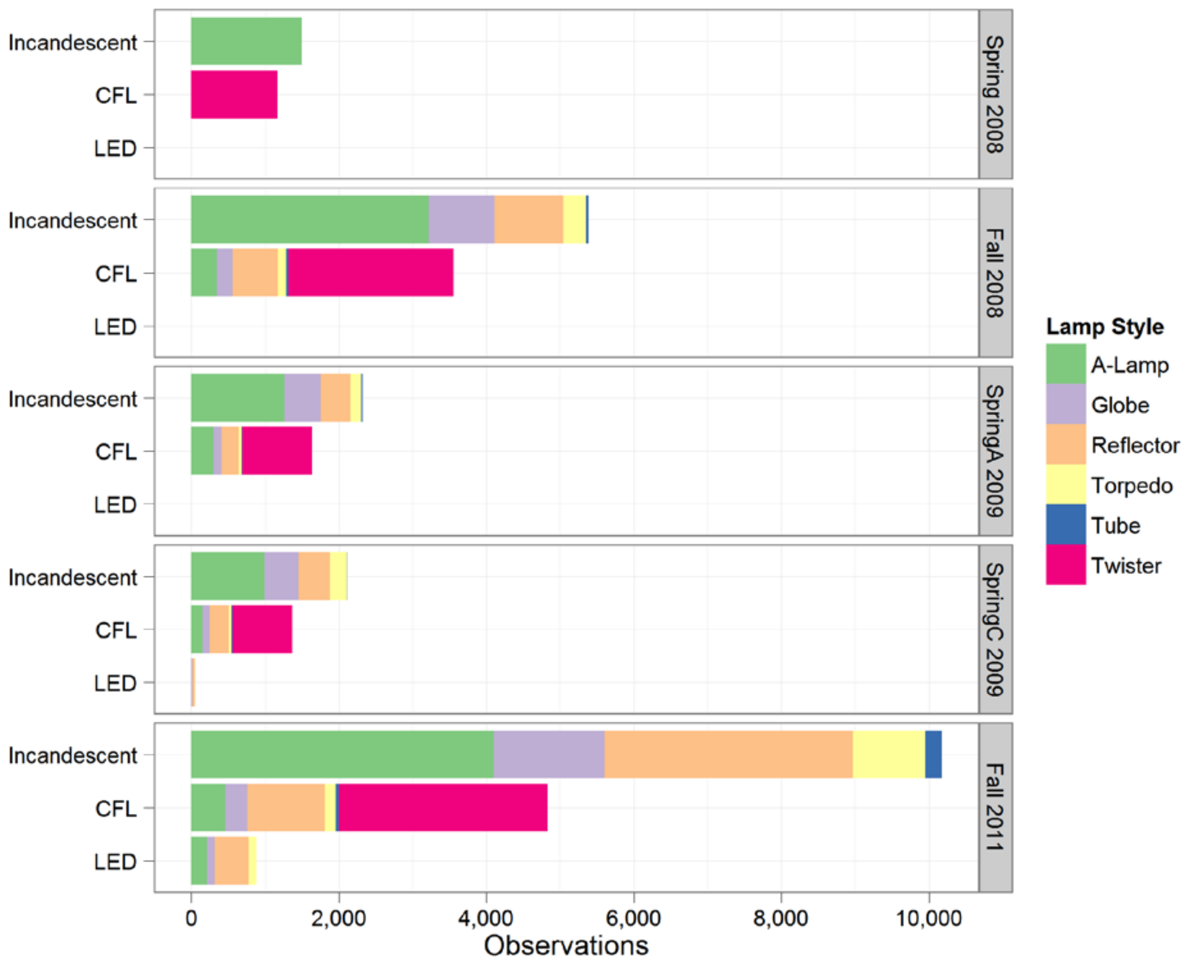
Table 1 Overview of the shelf survey collection waves

Period	No. of stores	No. of lamps	Type of data collected
Spring 2008	123	2,790	Only covered non-dimmable, single wattage, spiral MSB CFLs operating between 9 and 30 watts and A-Lamp shaped incandescent lamp equivalents. The survey did not include stores within SDG&E's territory.
Fall 2008	203	9,994	All MSB CFLs and incandescent equivalents and other lamps with package counts for discount, drug, and grocery channels.
SpringA 2009	76	4,285	All MSB CFLs and incandescent equivalents and other lamps.
SpringC 2009	48	5,824	Full lighting inventory and package counts (including LEDs). Included non-participating stores.
Fall 2011	184	23,775	Full lighting inventory and package counts (including LEDs).

The sampling plan for the Fall 2011 survey differs from prior surveys. The Fall 2011 survey stratified retail locations by channel and sampled 26 stores in each channel. In contrast, previous surveys sampled in proportion to program sales. The sample included more stores in channels with a higher proportion of lamp sales. There are two implications of the Fall 2011 sampling strategy: (1) computing average lamp prices requires weighting by channel and (2) oversampling lower volume channels gives the hedonic pricing model more observations for computing channel specific effects. See section 3 for a description of each retail channel.

Figure 1 presents the distribution of observations by survey wave and for each of the three main lighting technologies (i.e., incandescent, CFLs and LEDs). Each observation represents a unique lamp package within a store. As can be seen in the figure, the Fall 2011 shelf survey collected the largest number of observations.

Figure 1 Observations by collection wave, lamp technology, and lamp style



3. Scope

This study limits the research to replacement MSBs available through retail distribution channels. Retail channels included in this research are defined as follows:

- **Discount** – Retail stores that sell a wide variety of products at a deep discount. Many items typically sell for $1 or less. These stores do not feature food/groceries as their primary product. Examples include: 99 Cents Only, Dollar Tree, and Big Lots.

- **Drug** – Retail stores that feature prescription and over the counter drugs as well as a wide variety of other products. Examples include: CVS, Rite Aid, and Walgreens.

- **Grocery –** Retail stores that feature food/groceries and/or liquor as their primary product. The shelf surveys include stores from three grocery channel sub-categories:

    - *Large grocery stores* are national or regional chains that do not feature food and other products at a deep discount. They also typically sell both utility discounted and non-discounted light lamps. Examples include: Albertsons, Ralphs, and Safeway/Vons.

    - *Independent grocery stores* are almost always independently owned and typically have up to nine locations in a small geographic area. Independent grocery stores usually only sell utility discounted light lamps. Examples of independent grocery stores include Draegers Market, Laurel Street Grocery, and Spencer's Fresh Markets.

    - *Discount grocery stores* are usually larger chains that feature food and other products at a deep discount. Discount grocery stores usually only sell utility discounted light lamps. Examples of discount grocery stores include Grocery Outlet and Smart and Final.

- **Hardware –** Retail stores that feature hardware as their primary product. Hardware stores are typically independently owned (including hardware stores with national affiliations, such as Ace and True Value). Also included in this category are independently owned lumber stores that feature a small variety of light lamps. Examples include: Ace Hardware, True Value Hardware, Chino Lumber and Hardware, and Foothill Hardware.

- **Home Improvement –** Large retail stores that feature home improvement merchandise as their primary product. These stores are typically large national or regional chains. Examples include: Home Depot, Lowe's, Orchard Supply Hardware, and HD Supply.

- **Mass Merchandise –** Large retail stores that offer a very wide range of products, including clothing, appliances, electronics, and furniture. All mass merchandise stores are large national or regional chains. Examples include: Wal-Mart, Target, IKEA, and Kmart

- **Membership Club –** Large retail stores that offer a wide array of products, including food, clothing, electronics, and furniture. Many items sold at membership club stores are sold in bulk and at discounted prices. These stores require customers to purchase annual/semi-annual memberships in order to buy merchandise. All membership club stores are large national or regional chains. Examples include Costco and Sam's Club.

Other channels, such as lighting showrooms, electronics stores and online retailers, are not included in this study at this time.

This study also limits lamps to types commonly found in retail channels:

- **Incandescent, CFL, and LED lamp technologies –** The shelf surveys include observations of lamps that use cold cathode (9 observations across all shelf survey waves) and other technologies (224 observations). The limited number of cold cathode observations and limited detail on other lamp technologies preclude estimating hedonic pricing models for these technologies.

- **A-Lamp, globe, reflector, torpedo, twister, and tube lamp styles –** Other types of specialized lamps included in the shelf surveys —such as night lights, bug lights, post lights, circline lamps and others (820 observations all together)—are not included in this study.

4. Data Preparation

The DNV KEMA team implemented the following steps to combine the data collected from the five waves into one common dataset:

- **Mapped variables to a common naming convention –** Appendix A lists each of the variables in the combined dataset and shows their origin. Some of the data in the combined dataset are the results of calculations rather than direct observations.

- **Recoded the retail channels –** DNV KEMA recoded the retail channel for twelve retail chains for consistency across survey waves.

- **Flagged unusable observations –** These include observations with:
  - *Duplicates (626 observations).* The data collectors recorded lamp packages separately for each location in the store. For the purpose of an estimation dataset, the duplicates are identical observations. DNV KEMA combined the observations and preserved the total package count per store.
  - *Pricing inconsistencies (5 observations).* Some observations have a full price less than discounted price. Due to the logical inconsistency, these records will not be used for hedonic estimation.
  - *Unrealistically low LED prices (3 observations).* LED lamps are almost always priced over $15 per lamps. Three observations have unrealistically low prices under $3 per lamp.

- *Very low-wattage incandescent lamps.* DNV KEMA could not verify the existence of incandescent lamps that operate with less than 1 watt.

- *Very high-wattage incandescent lamps (501 observations).* Incandescent lamps that use 200 watts or more are either incorrectly coded or intended as a swimming pool heat lamp.

- *Very high-wattage CFLs (37 observations)*. CFLs that use 70 watts or more are either incorrectly coded or meant for commercial use.

The checks described above verified 240 lamp model numbers and corrected the coding on 85 lamps. Around 1,000 observations were excluded because they were missing information about the full price (i.e., non-discounted price) and/or about the discounted price. Where that is the case, the observations are not usable for the hedonic pricing model but will be valuable for retail channel weighting.

Table 2, Table 3, and Table 4 show the number of usable observations for incandescent lamps, CFLs, and LED lamps by style, application, collection wave and retail channel. Note that the shelf surveys only recorded LED lamps in the SpringC 2009 and Fall 2011 collection waves. The lamp application is one of the following:

- **Dimmable –** CFLs that respond to a dimming controller. CFLs require special circuitry for dimming, unlike incandescent and LED lamps.

- **3-way –** Lamps that operate at three discrete lighting levels.

- **General use –** Lamps not covered in one of the above categories. DNV KEMA marked observations missing dimmable and 3-way indicators as general use lamps.

Table 2 Incandescent lamp observations by collection wave, retail channel, application, and style

Wave	Retail Channel	3-way				General				
		A-Lamp	Globe	Reflector	Torpedo	A-Lamp	Globe	Reflector	Torpedo	Tube
Spring 2008	Discount	.	.	.	.	38	.	.	.	.
	Drug Store	.	.	.	.	338	.	.	.	.
	Grocery	.	.	.	.	135	.	.	.	.
	Hardware	.	.	.	.	344	.	.	.	.
	Home Improvement	.	.	.	.	253	.	.	.	.
	Mass Merchandise	.	.	.	.	374	.	.	.	.
	Membership Club	.	.	.	.	11	.	.	.	.
	All	.	.	.	.	1,493	.	.	.	.
Fall 2008	Discount	14	.	1	.	191	27	9	1	.
	Drug Store	77	.	.	.	252	52	71	16	.
	Grocery	113	.	.	.	685	103	177	18	4
	Hardware	96	.	.	.	420	134	175	72	5
	Home Improvement	155	6	.	1	623	326	292	113	4
	Mass Merchandise	101	.	.	.	490	246	202	91	17
	Membership Club	.	.	.	.	.	.	1	.	.
	All	556	6	1	1	2,661	888	927	311	30
SpringA 2009	Discount	6	.	1	.	100	5	6	2	.
	Drug Store	22	.	.	.	80	18	27	.	.
	Grocery	49	.	.	.	407	103	88	16	2
	Hardware	10	.	.	.	62	25	37	8	.
	Home Improvement	48	1	.	.	178	173	129	44	.
	Mass Merchandise	39	1	.	.	263	163	111	81	15
	Membership Club									
	All	174	2	1	.	1,090	487	398	151	17
SpringC 2009	Discount	1	.	.	.	17	5	3	3	.
	Drug Store	19	.	.	.	79	45	25	15	2
	Grocery	16	.	.	.	40	21	13	7	.
	Hardware	4	.	.	.	34	16	14	16	.
	Home Improvement	95	.	1	.	450	275	319	136	5
	Mass Merchandise	39	.	.	.	191	101	60	48	.
	Membership Club	.	.	.	.	.	.	1	.	.
	All	174	.	1	.	811	463	435	225	7
Fall 2011	Discount	3	.	.	.	88	67	27	22	10
	Drug Store	133	.	.	.	506	149	245	103	24
	Grocery	69	.	.	.	257	50	110	27	8
	Hardware	158	.	.	.	932	439	1,039	353	81
	Home Improvement	178	.	.	.	1,066	468	1,468	307	53
	Mass Merchandise	115	.	.	.	593	321	486	166	50
	Membership Club	.	.	.	.	6	-	2	-	-
	All	656	.	.	.	3,448	1,494	3,377	978	226

Table 3 CFL observations by collection wave, retail channel, application, and style

Wave / Retail Channel		3-way			Dimmable				General					
		A-Lamp	Tube	Twister	A-Lamp	Reflector	Torpedo	Twister	A-Lamp	Globe	Reflector	Torpedo	Tube	Twister
Spring	Discount	.	.	.	.	.	.	.	.	.	.	.	.	48
2008	Drug Store	.	.	.	.	.	.	2	.	.	.	.	.	253
	Grocery	.	.	.	.	.	.	.	.	.	.	.	.	38
	Hardware	.	.	1	.	.	.	.	.	.	.	.	.	228
	Home Improvement	.	.	.	.	.	.	.	.	.	.	.	.	276
	Mass Merchandise	.	.	.	.	.	.	7	.	.	.	.	.	165
	Membership Club	.	.	.	.	.	.	.	.	.	.	.	.	24
	All	.	.	1	.	.	.	9	.	.	.	.	.	1,032
Fall	Discount	.	.	1	.	1	.	.	5	4	22	1	1	69
2008	Drug Store	.	.	12	.	6	.	19	29	20	33	10	.	233
	Grocery	.	.	9	.	9	.	3	31	15	57	19	2	325
	Hardware	.	.	18	.	11	.	11	25	22	56	18	11	207
	Home Improvement	1	.	39	1	28	7	18	75	60	198	15	6	604
	Mass Merchandise	.	.	24	.	21	.	41	172	75	135	40	3	576
	Membership Club	.	.	7	.	7	.	.	10	9	31	6	2	21
	All	1	.	110	1	83	7	92	347	205	532	109	25	2,035
SpringA	Discount	.	.	.	.	.	.	.	1	1	1	.	.	44
2009	Drug Store	.	.	3	.	2	.	2	7	3	11	1	.	63
	Grocery	.	.	6	.	7	.	10	25	11	39	8	.	194
	Hardware	.	.	2	.	2	.	.	1	1	4	.	.	23
	Home Improvement	.	.	10	.	8	1	7	40	33	71	6	6	217
	Mass Merchandise	.	.	12	5	23	.	20	215	55	61	16	.	319
	Membership Club	.	.	4	.	.	.	.	4	2	10	1	2	7
	All	.	.	37	5	42	1	39	293	106	197	32	8	867
SpringC	Discount	.	.	.	.	.	.	.	1	2	2	.	.	13
2009	Drug Store	.	.	2	.	1	.	1	3	2	4	4	.	41
	Grocery	.	.	.	.	1	.	.	4	1	3	3	.	24
	Hardware	.	.	1	.	.	.	2	1	1	2	3	1	2
	Home Improvement	.	.	25	.	26	.	25	57	55	134	5	14	415
	Mass Merchandise	.	.	11	.	10	.	10	77	29	44	18	.	208
	Membership Club	.	.	4	.	8	.	1	7	6	27	.	2	23
	All	.	.	43	.	46	.	39	150	96	216	33	17	726
Fall	Discount	.	.	1	.	.	.	.	2	2	7	1	-	18
2011	Drug Store	.	.	20	.	28	.	30	78	35	90	31	-	377
	Grocery	.	.	7	.	9	.	6	22	7	28	8	1	153
	Hardware	.	1	29	6	42	.	35	79	43	131	32	22	441
	Home Improvement	.	.	50	.	105	10	85	127	108	363	40	18	921
	Mass Merchandise	.	.	34	.	32	.	33	134	85	131	22	6	498
	Membership Club	.	.	3	.	20	.	.	12	24	53	6	-	79
	All	.	1	144	6	236	10	189	454	304	803	140	47	2,487

Table 4 LED observations by collection wave, retail channel, application, and style

Wave / Retail Channel		A-lamp	Globe	Reflector	Torpedo
SpringC 2009	Disount	-	-	-	-
	Drug Store	-	-	-	-
	Grocery	-	1	-	1
	Hardware	-	4	12	4
	Home Improvement	-	-	10	-
	Mass Merchandise	-	4	14	-
	Membership Club	-	9	36	5
	All	-	18	72	10
Fall 2011	Disount	-	-	-	3
	Drug Store	11	-	-	4
	Grocery	12	13	53	13
	Hardware	159	58	358	65
	Home Improvement	17	13	10	8
	Mass Merchandise	23	22	42	18
	Membership Club	222	106	463	111
	All	444	212	926	222

5. Price-Attribute Relationships

This section examines the relationships between the sale price and key attributes for incandescent, CFL and LED lamps. These relationships provide expectations for the hedonic pricing model that DNV KEMA will estimate as part of this study.

Price distributions are shown using box and whisker plots. The box and whisker plot gives a concise, graphical summary of the distribution range. The box captures the inter-quartile range (IRQ), i.e. between the first and third quartiles, and the whiskers extend to 1.5 times the IRQ. The box and whisker plot shows points that fall outside of this range as individual points. The vertical line within the box is the median value of the distribution.

This section is organized into three subsections; one for each lamp type. The first figure in each subsection shows price variation across collection wave. The subsequent figures show the relationship using Fall 2011 shelf survey only.

5.1 Incandescent Lamps

Figure 2 shows the price distribution by collection wave, lamp style, and application. The primary intention of this plot is to show differences in collection waves. The lamp styles (e.g., A-Lamp, Globe, etc.) and application (e.g., 3-way and general use) should have significant influences on the price distributions. The plot shows conditional distributions as the lamp style and retail channel explain much of the price variation.

The plot shows several key features of these data:

- Lamp prices are compact and ranges from $0.12 to $30 per lamp. Conditioning the price distribution into waves, styles, and application captures a large amount of the variation.
- The price distributions vary by collection wave. The median bulb prices within each style and application tend to increase over time. However, this plot does not account for changes to the product mix with the lamp style categories.
- At least 90% of the lamps (other than reflectors) have price of $5 or less.
- Reflectors have a wider distribution and larger price range than other styles. The Fall 2011 collection wave has relatively wider price range for A-Lamps and reflectors.

Overall, the plot suggests that there are some differences in the collection waves. The hedonic pricing model will need to control for these differences.

Figure 2 Incandescent Lamp price distribution by collection wave, style and application

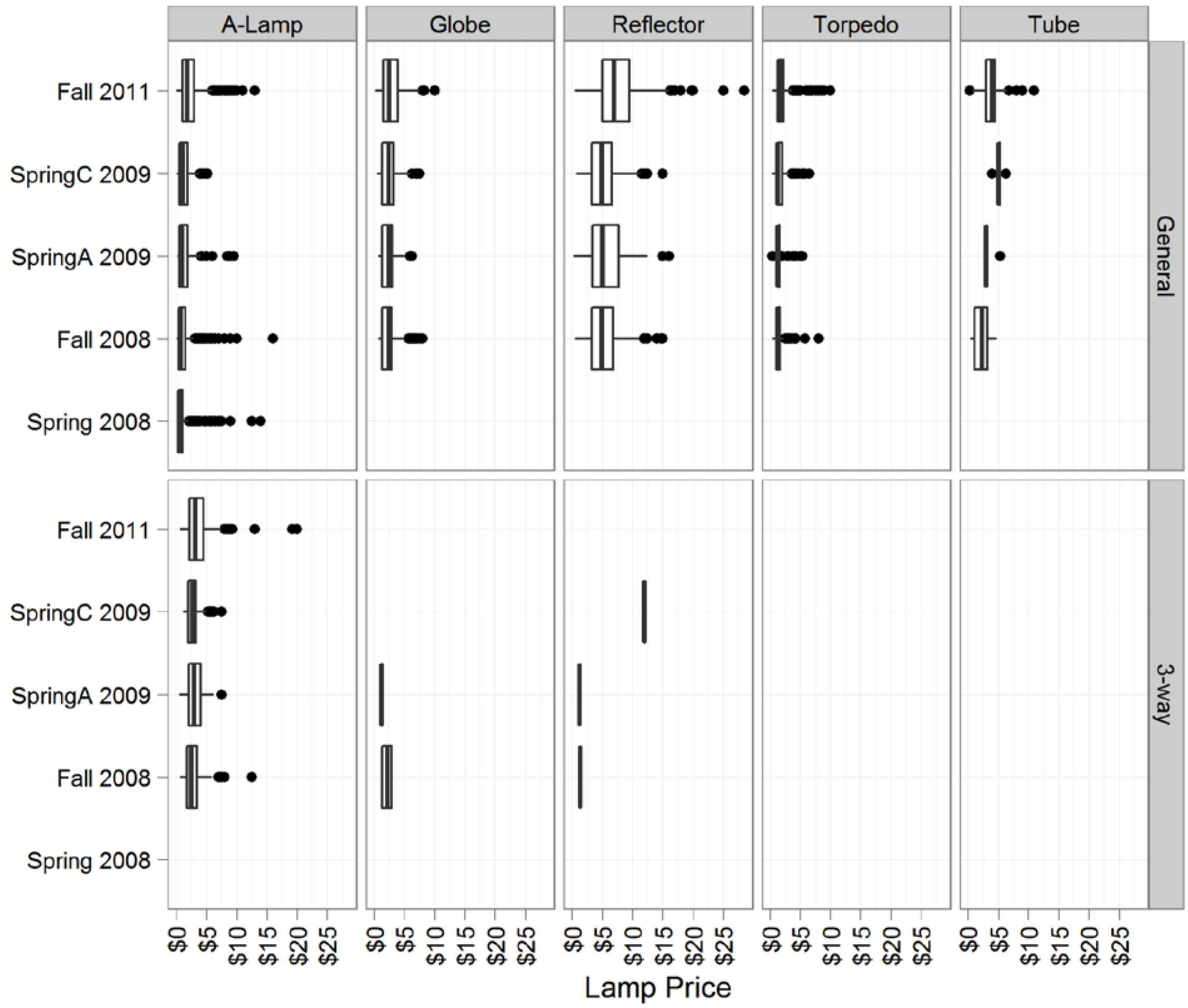


Figure 3 shows the price distribution by retail channel, style, and application. The plot shows that the retail channel explains much of the variation in the price distribution. Mass merchandise, membership clubs, and discount stores sell lamps at a price noticeably less than in other retail channels. The selection of lamps within channels also varies considerably. For example, home improvement stores have more lamp types than discount and membership club stores. Additionally, certain retailers have their own store brands and discount stores typically do not sell well-know national brands. The plot suggests that the retail channel where a lamp is sold helps explain the unit price of a lamp. However, that may be in part due to the brand stocking patterns.

Figure 3 Incandescent lamp price distribution by retail channel, style and application

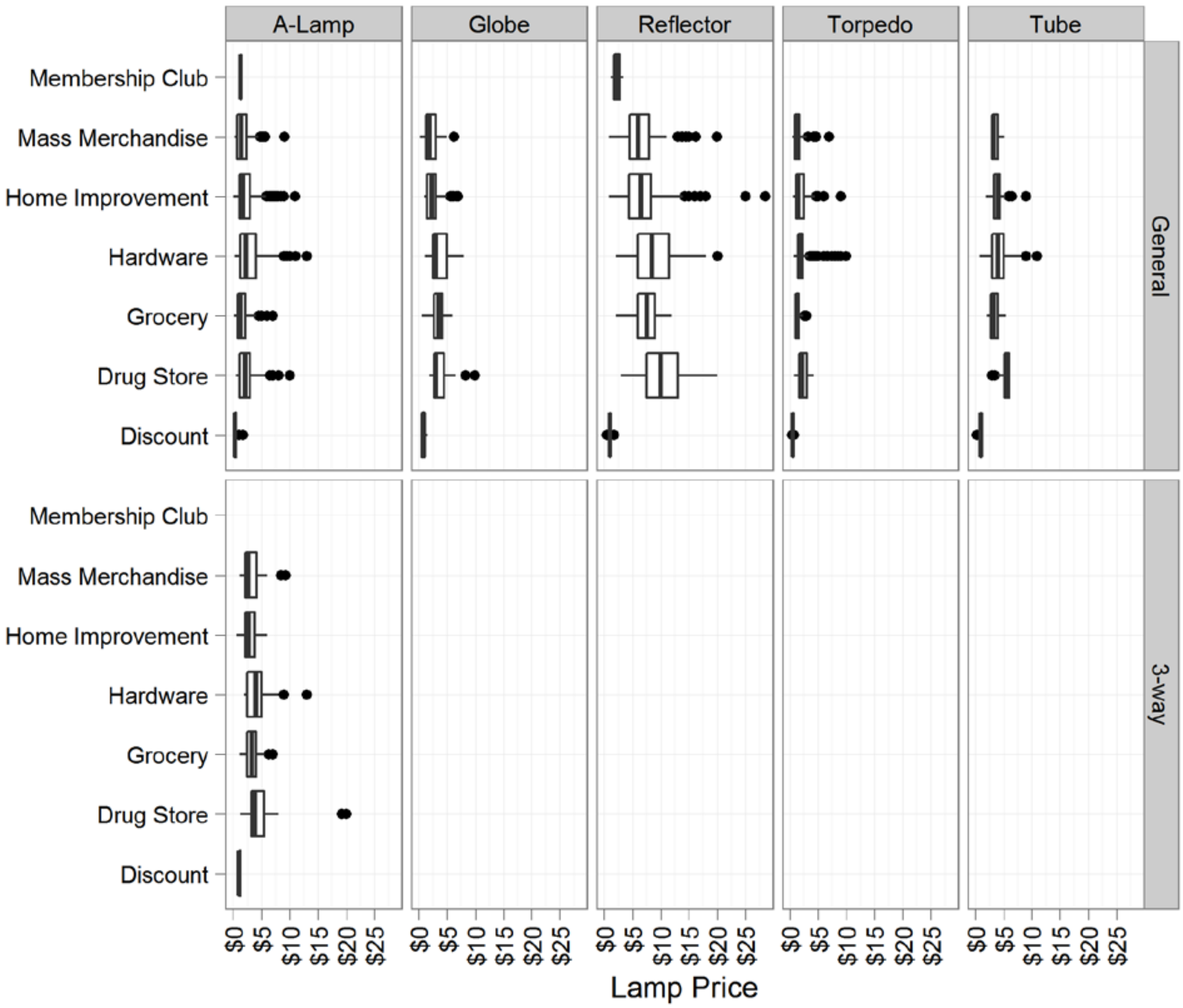


Figure 4 shows a scatter plot of lamp prices by wattage for lamp styles and application. The blue line shows the linear trend. A lamp's wattage is a rating of how much power the lamp will consume on standard (120 volt, 15 amp) residential circuit. The relationship between wattage and price is complex:

- The practice of marking incandescent lamps with the wattage level results in vertical lines on the scatter plot. Manufacturers cluster lamp wattages into common wattage levels (e.g., 30, 40, and 60).
- Lamp prices tend to rise with watts for general use reflectors, for example, but remain constant for general use tubes.

- The price range within each category is relatively large. This suggests that wattage by itself is not sufficient for approximating the lamp price.

This plot shows that the hedonic pricing model will need to account for a complex relationship between price and watts that vary by style and application.

Figure 4 Incandescent lamp price distribution by wattage, style and application

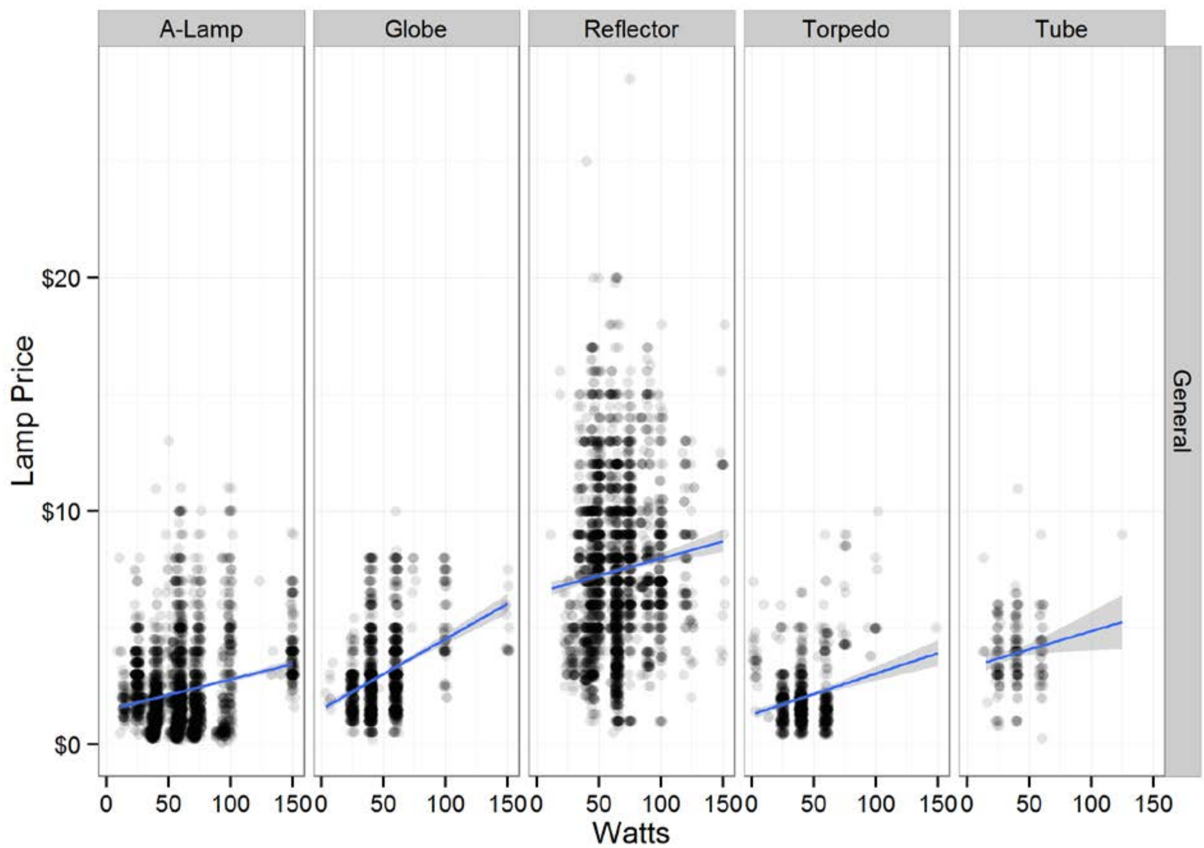


Figure 5 shows the relationship between lumens and price by style and application. Lumens are a measure of lamp brightness. Lamp packaging typically convey brightness using wattage rather than lumens. However, lumens measure brightness whereas wattage is strictly a measure of power. Like the graphs of price and wattage, the graphs of price and lumens show complex relationships:

Past shelf surveys did not capture lumens as frequently as they recorded wattage. This results in fewer points in the scatter plot.

- The lumen domain is much more contiguous than the wattage domain. The clear clustering effect on wattage levels (shown in Figure 5) is not nearly as prominent in this plot of lumens.

- The plot shows a relationship between price and lumens for globe and torpedo-styled lamps. The plots do not present evidence of a strong relationship between lumens and price for other lamp styles.

Overall, the lumen level of a lamp appears to offer some explanatory power on the price of a lamp. However, the relationship is not direct and needs to account for other attributes such as retail channel. Wattage and lumens are highly correlated. This may prevent the hedonic pricing model from including both of these lamp attributes directly.

Figure 5 Incandescent lamp price distribution by lumens, style, and application

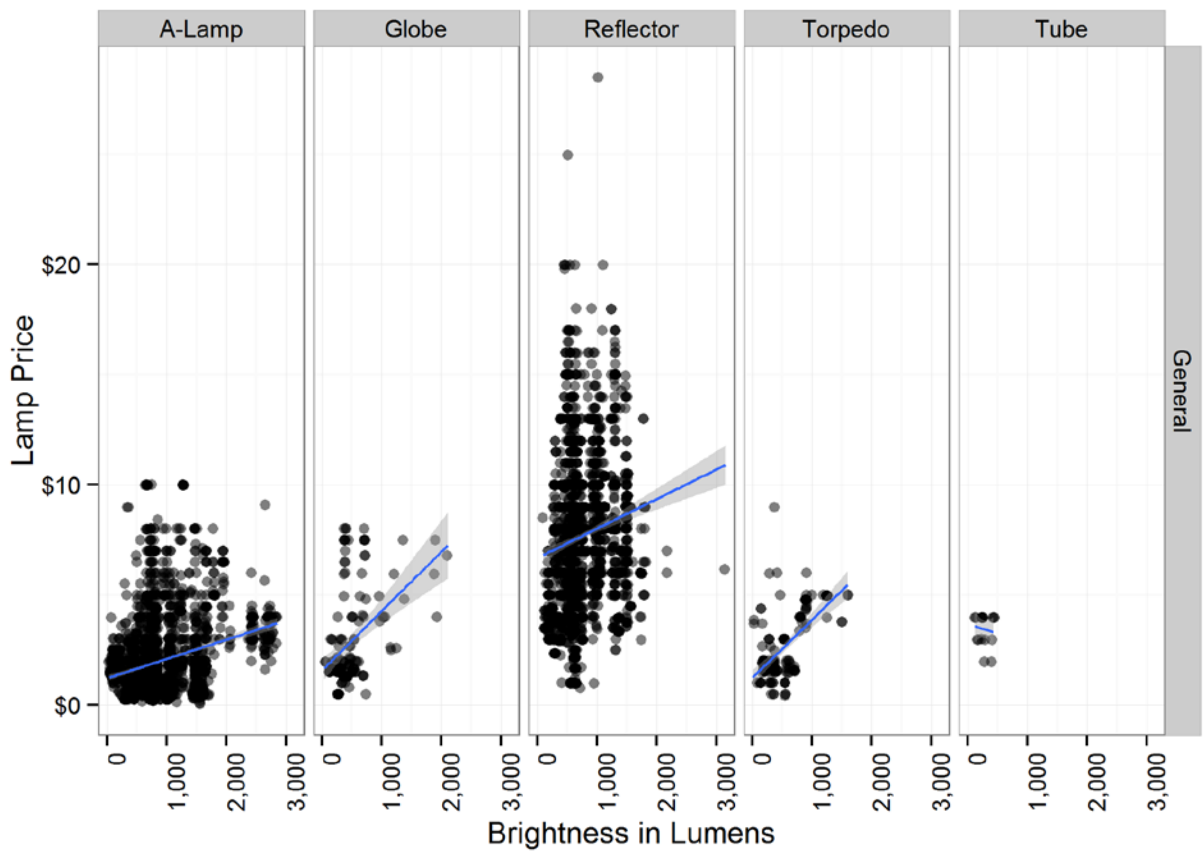


Figure 6 shows the relationships between lamp price and rated life hours of use by lamp style and application. The rated hours of use are the nominal hours that a lamp will last before burnout. There are a few aspects that are worth noting:

- The rated life of most lamps is less than 5,000 hours although there are a handful of lamps that rated life of up to 15,000 hours.

- Manufacturers report rated life in rounded numbers. This results in the vertical lines that appear in the plots.
- There is a positive relationship between longer life and higher prices for A-Lamps.

The relationship between price and rated life is mostly positive. Incorporating the rated life will help increase explanatory power in the hedonic price model. However, other lamp attributes not controlled for in the plot could confound the relationship between price and rated life hours.

Figure 6 Incandescent lamp price distribution by rated life, style, and application

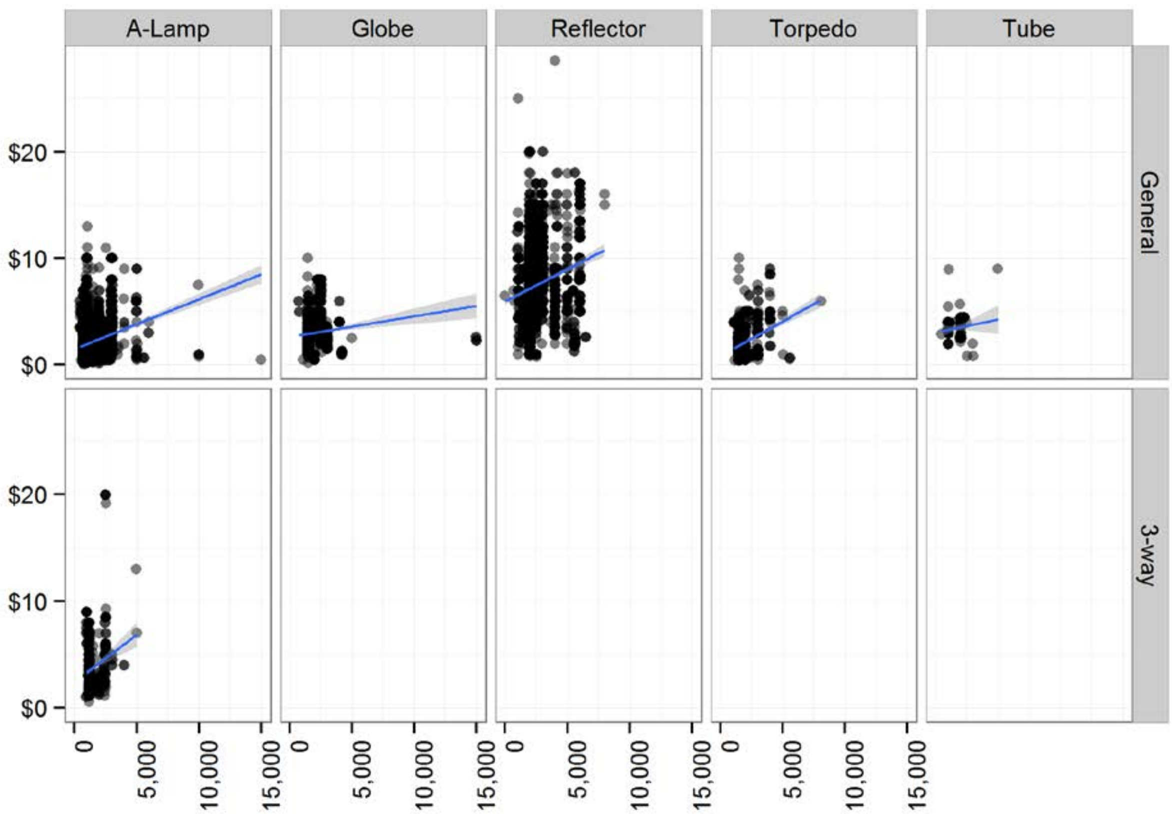


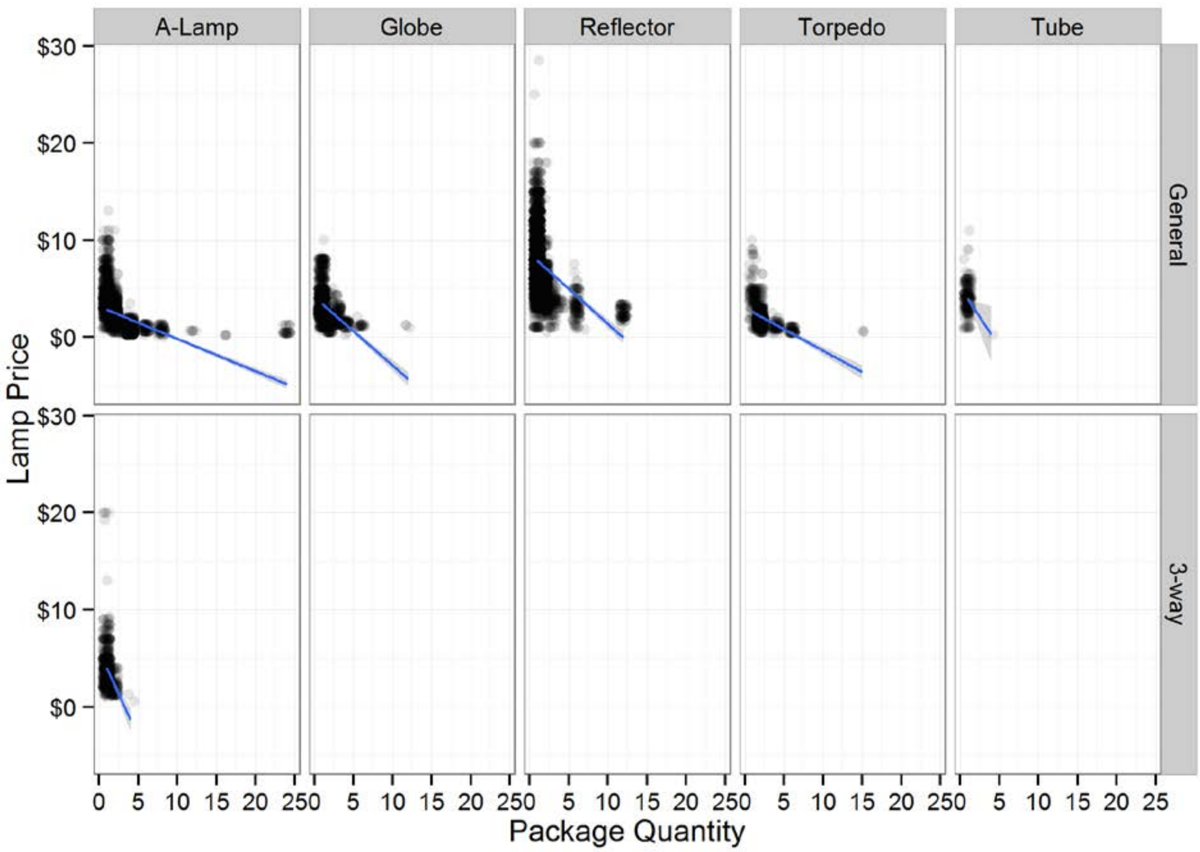
Figure 7 shows the relationships between the number of lamps in a package and the price of lamps in the package. This plot presents clear relationships:

- The plots show variation in package quantity by style and application. The more common styles, e.g., A-Lamps, have more quantity options than less common lamp styles.

- There is a strong inverse relationship between price and package quantity. The per-lamp price on a package with two lamps is much less than the price of just one lamp, indicating a non-linear relationship.

The plot presents evidence that including the package quantity will have explanatory power in the hedonic pricing model.

Figure 7 Incandescent lamp price distribution by package quantity, style and application



5.2 CFLs

Figure 8 shows the lamp price distribution of CFLs by shelf survey collection wave, lamp style, and lamp application. The plot shows several characteristics about CFLs that the hedonic pricing model needs to incorporate:

- Not all applications are available for each lamp style. Three-way lamps are only available for twisters in the shelf survey data. Dimmable lamps are not available in either globe or torpedo styles in the shelf survey data.

- CFL prices range from $0.16 to $30 per lamp. The plots show a slight trend of CFL price increases over time. However, this plot does not account for changes to the product mix with the lamp style categories.
- Twister-styled lamps that are either 3-way, or dimmable have higher prices.
- Nearly all the distributions have compact “box” and long whiskers. This indicates that the majority of prices are within a tight range.
- The more common lamp styles, twister and A-Lamp, tend to cost less than other styles.

Overall, the plot shows that the data have some differences by collection wave. There is an opportunity to explore changes over time in the hedonic price model.

Figure 8 CFL price distribution by collection wave, style and application

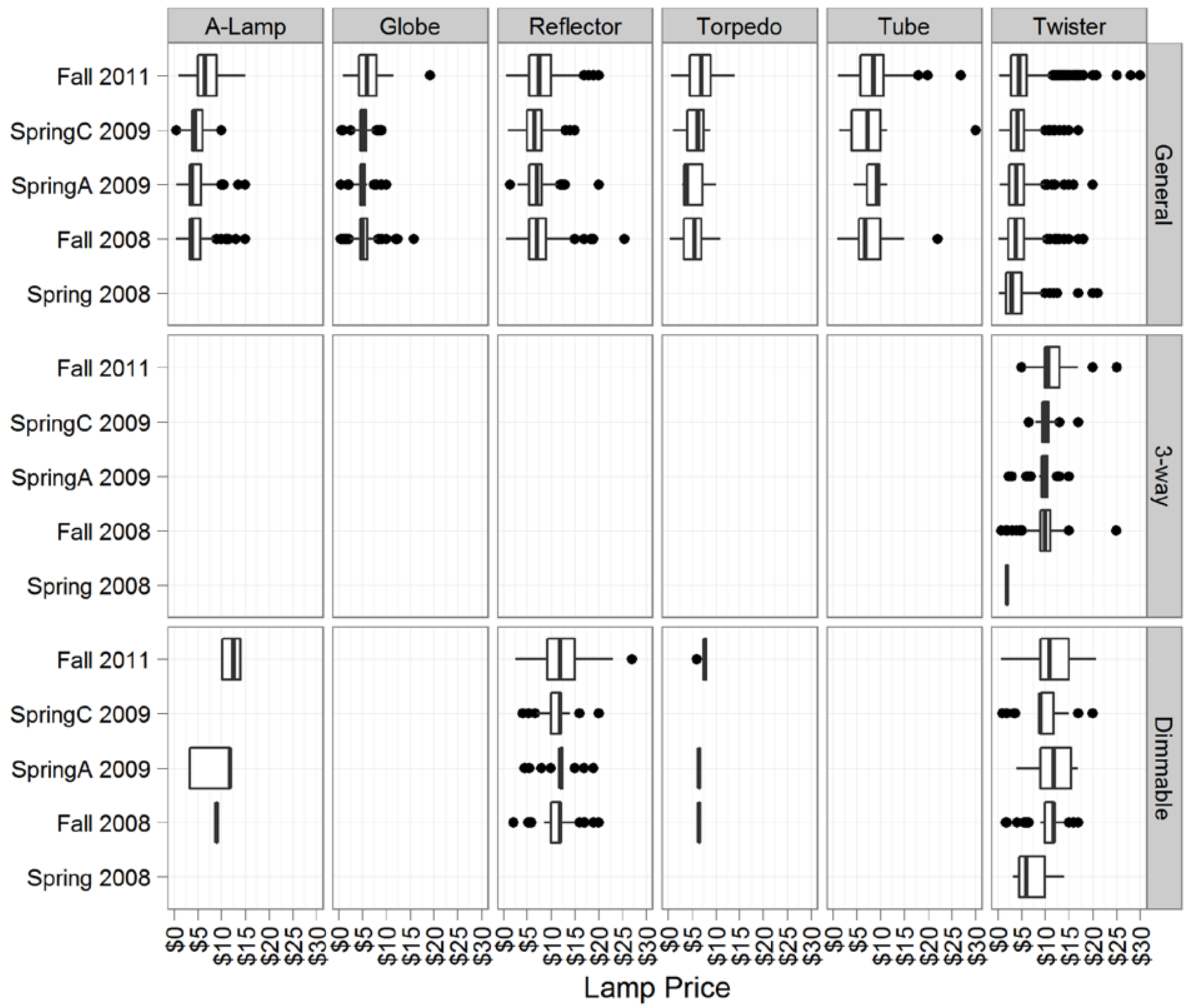


Figure 9 shows how CFL prices vary by retail channel, lamp style and application. Like incandescent lamps, there is a pronounced difference in both the price and availability of CFLs by retail channel. The plot shows several relationships:

- There is a consistent relationship between the price distributions by retail channel. Discount store and membership stores tend to have lower prices, with drug stores and grocery stores tending to have higher CFL prices
- Availability varies by retail channel. Discount stores and drug stores covered by the survey do not stock dimmable and tube CFLs, respectively. There are a large amount of outliers (denoted with black dots) in many of the plots. This occurs when the distribution has a long tail. The

interpretation is that the combination of retail channel, lamp style, and application do not account for all of the variation in lamp prices.

The plot confirms that the retail channel plays an important part in explaining lamp prices. The hedonic pricing model will need to reflect that not all lamp styles and applications are available for all retail channels.

Figure 9 CFL price distribution by retail channel, style, and application

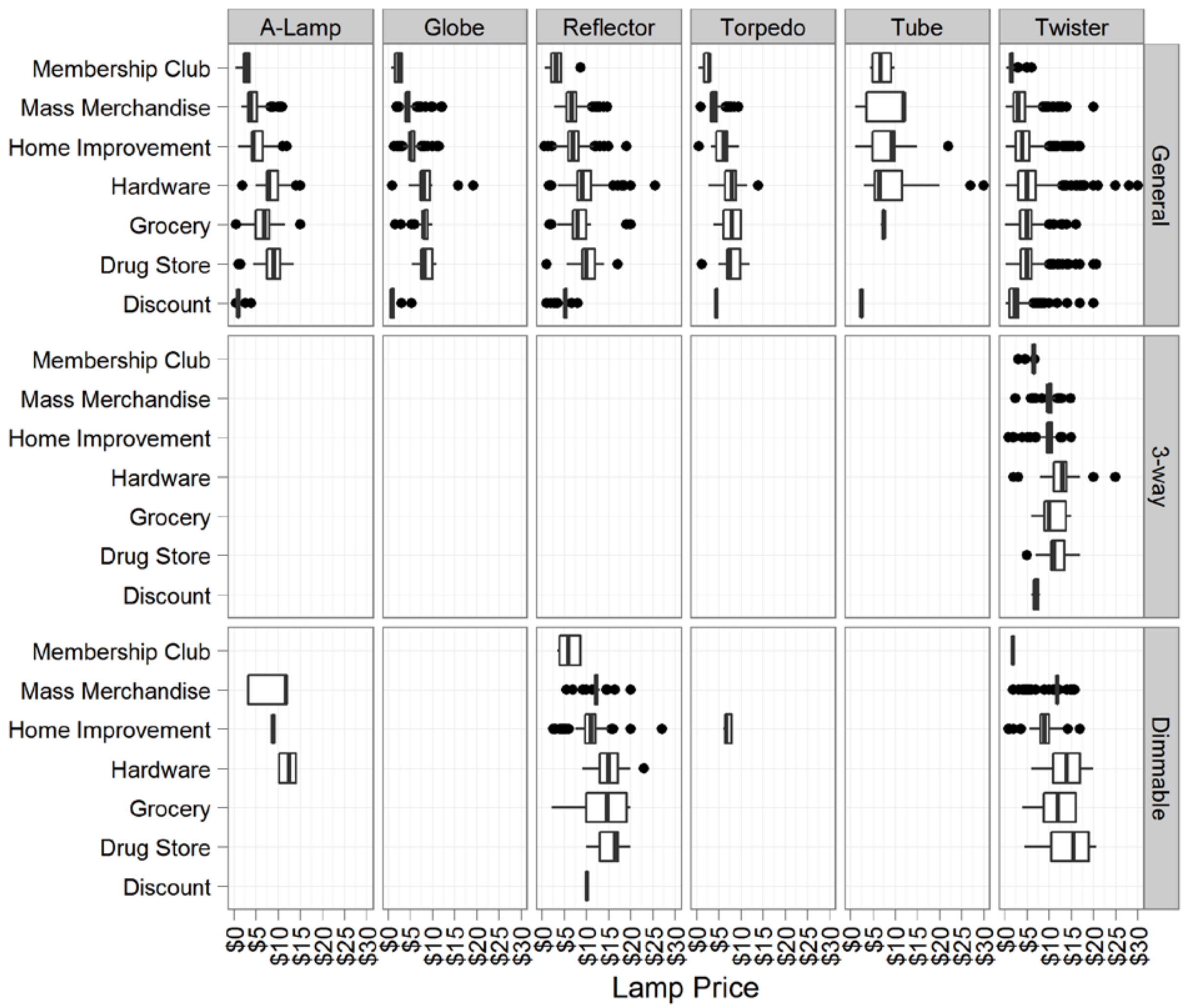


Figure 10 shows the relationship between lamp price and wattage by retail channel and application. The wattage range for CFLs is small compared to incandescent lamps. The high end of the CFL wattage is 60 watts while the high end of the incandescent lamps is 150 watts. The scatter plot shows several relationships that are important for the hedonic pricing model to capture:

- The price range for CFLs is relatively large compared to incandescent lamps. Within twisters, for example, prices ranges from around a $1 per lamp to $15 per lamp.
- The wattage domain for A-Lamps, globes, and torpedoes is narrow. The difference between the minimum and maximum wattage for globe CFLs is around 10 watts.
- Twisters and tube CFLs show visual evidence of a positive relationship between wattage and price.

The price variation in the plot is relatively large compared to the wattage variation. Other lamp attributes not controlled for in the plot could confound the relationship between price and lamp wattage. For non-twister CFLs (except tube), lamp wattage may not have explanatory power after controlling for lamp style and application.

Figure 10 CFL price distribution by wattage, style, and application

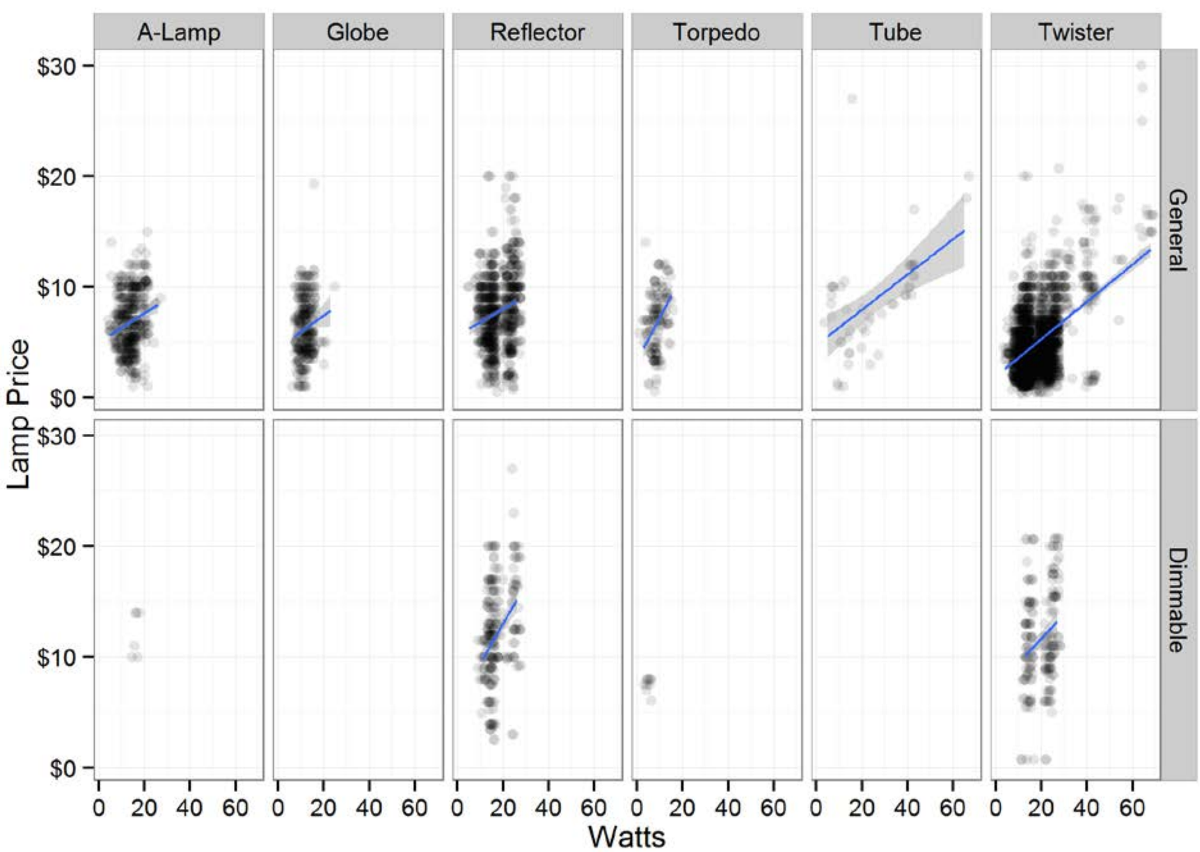


Figure 11 shows the relationship between CFL price and lumens by lamp style and application. There are a couple key differences between this plot and the related plot of lamp price and wattage:

- Except for twisters, the lumen output for lamps appears to be step values rather than the more continuous values in Figure 10.
- The strong vertical bars on the scatter plot suggest that the lamp price is not a function of the brightness for most lamp categories.
- Twisters and tubes include some higher lumen lamps. Here, the graphs show evidence that the price increases with brightness.

The brightness of a lamp may add explanatory power to the model. However, the high correlation between lumens and watts may prevent including both terms in the hedonic pricing model.

Figure 11 CFL price distribution by lumens, style, and application

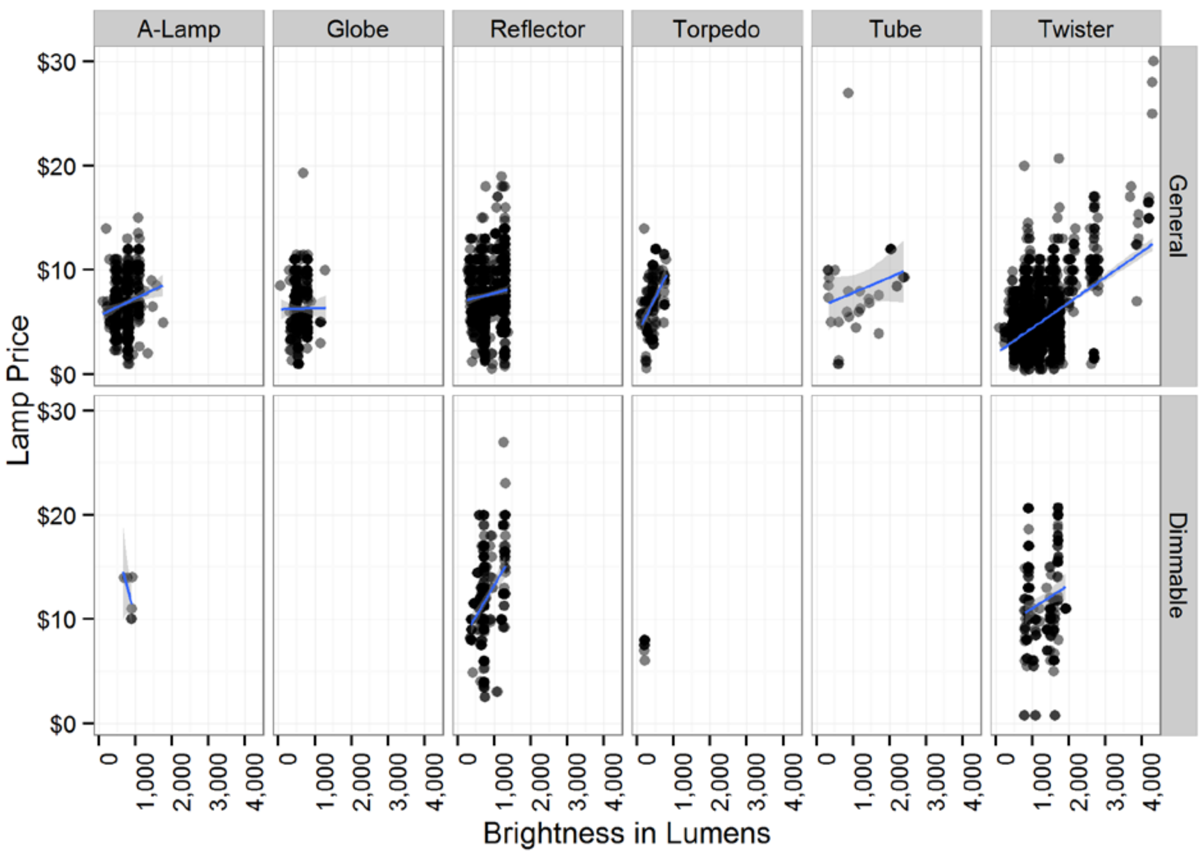


Figure 6 shows the relationships between lamp price and rated life hours of use by lamp style and application. The rated hours of use are the nominal hours that a lamp will last before burnout. There are a few aspects that are worth noting:

- The rated life of most lamps is less than 10,000 hours. The rated life for dimmable globes is an exception and warrants further explanation.
- Manufacturers report rated life in rounded numbers. This results in the vertical lines that appear in the plots.
- There are mixed relationships between longer life and prices.

The relationship between price and rated life is mostly flat or nonlinear. Incorporating the rated life will may increase explanatory power in the hedonic price model. Rated life is not likely to enter the regression as a linear explanatory term. However, other lamp attributes not controlled for in the plot could confound the relationship between price and rated life hours.

Figure 12 CFL price distribution by rated life, style, and application

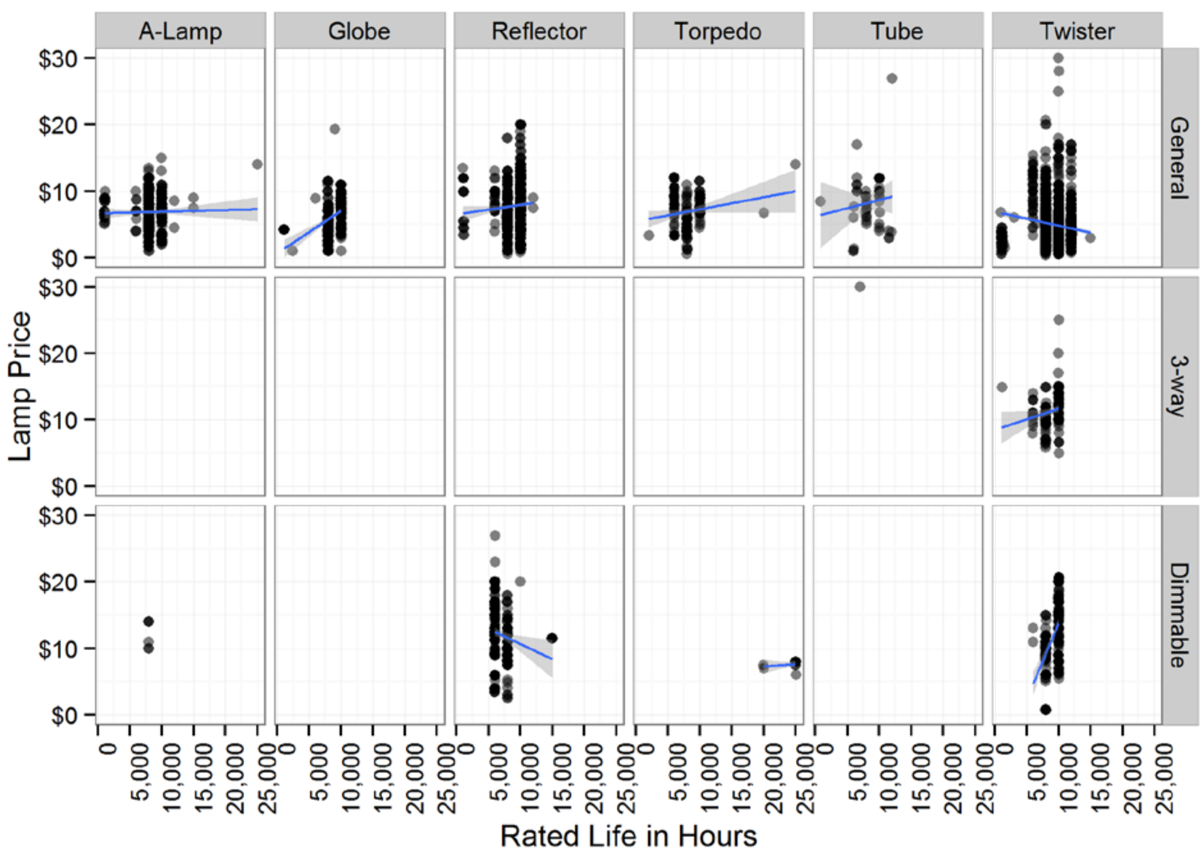
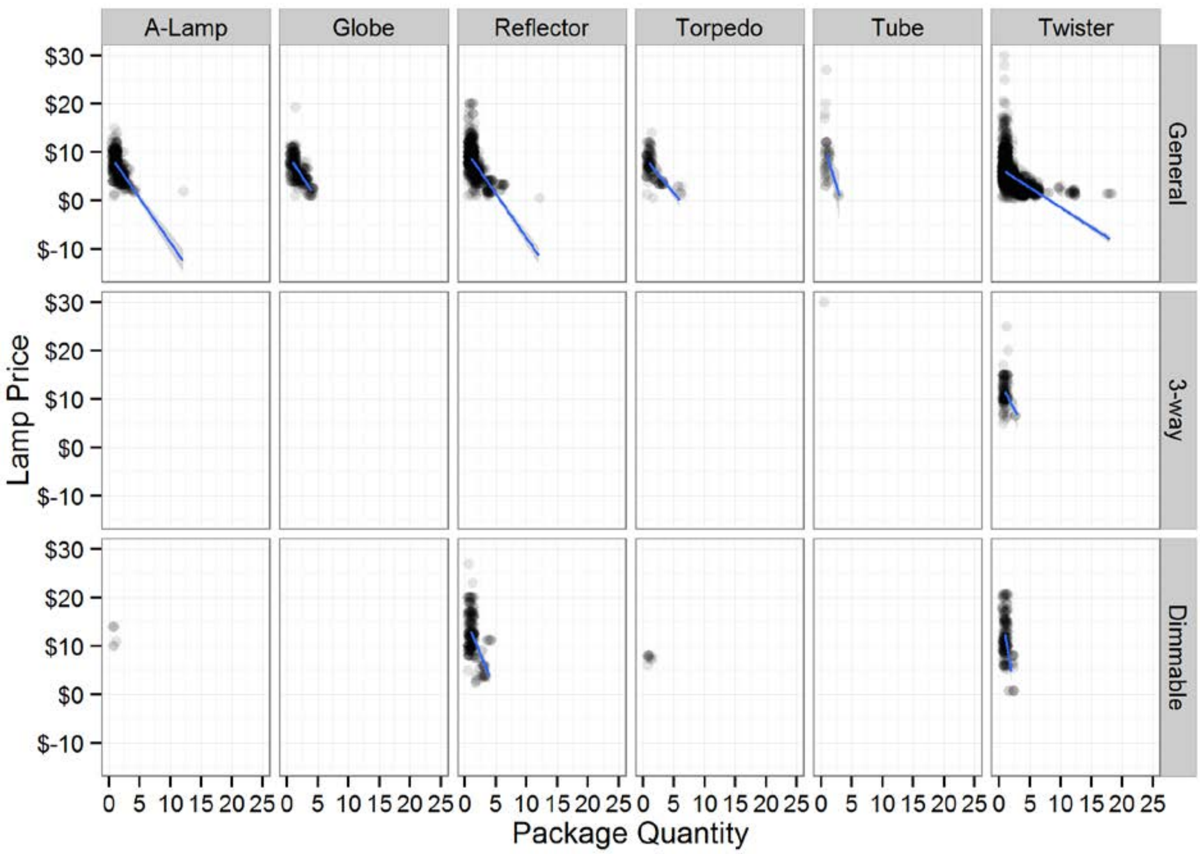


Figure 12 shows the relationships between the number of CFLs in a package and the price of lamps in the package. Like the corresponding plot for incandescent lamps, this plot presents clear relationships:

- CFLs are generally in smaller package sizes than incandescent lamps.
- There is a strong inverse relationship between price and package quantity. The price per lamp on a package with two lamps is much less than the price of just one lamp.

The plot presents evidence that including the package quantity will have explanatory power in the hedonic pricing model.

Figure 13 CFL price distribution by package quantity, style, and application



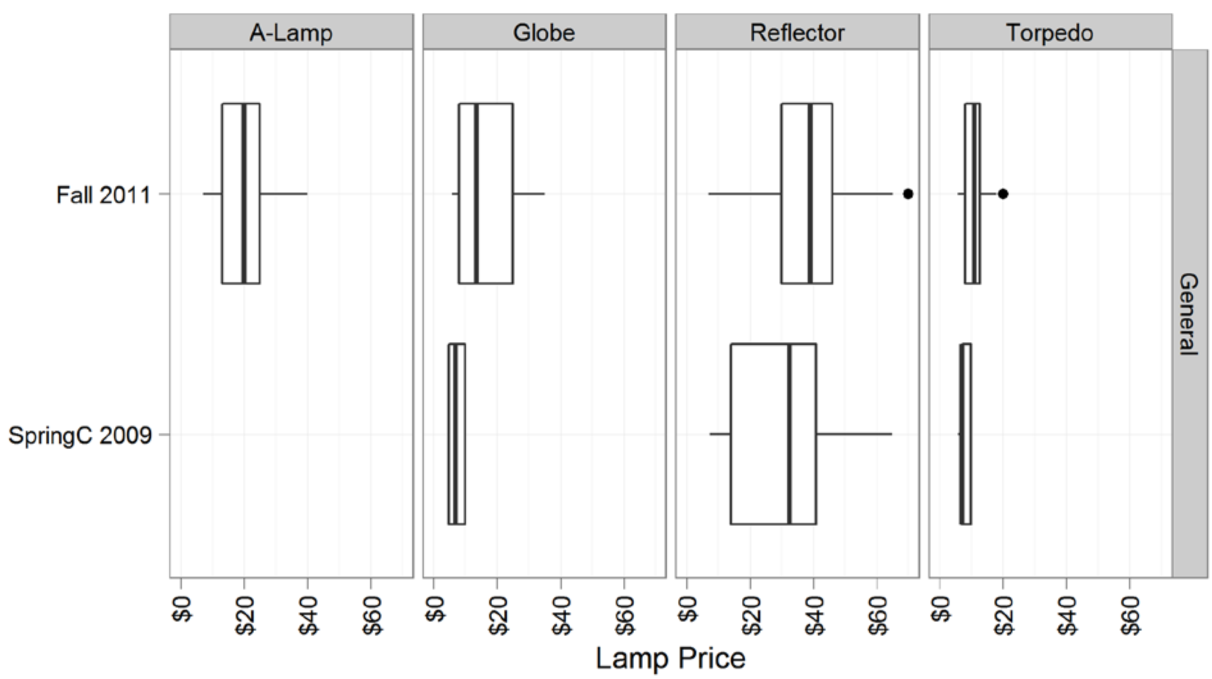
5.3 LED Lamps

Figure 13 shows the distribution of LED lamp price by collection wave, lamp style, and application. The SpringC 2009 and Fall 2011 shelf surveys were the only waves to include LED lamps. Note that the survey did not find LED lamps specifically labeled for use in three-way applications. LED lamps, like incandescent lamps, are inherently dimmable[2]. The plot highlights several aspects of the lamp prices:

- The distribution of LED lamp prices in Fall 2011 appear higher than the comparable distributions in the SpringC 2009 collection wave. This may be due to a variety of factors including, an increase in LED lamp options in Fall 2011.
- LED A-Lamps were not recorded in SpringC 2009 collection wave.
- LED reflectors have noticeably higher prices than other LED lamps.
- The price ranges for LED lamps are much larger than for other lamp technologies. LED lamps range in price between $5 and $60 per lamp.

The LED lamp price distributions in the two collection waves appear different, likely because the SpringC 2009 survey only covered 50 LED lamps while Fall 2011 covered more than 900 lamps. The hedonic pricing model will need to account for the difference in the price distribution across waves.

Figure 14 LED price distribution by collection wave, style, and application



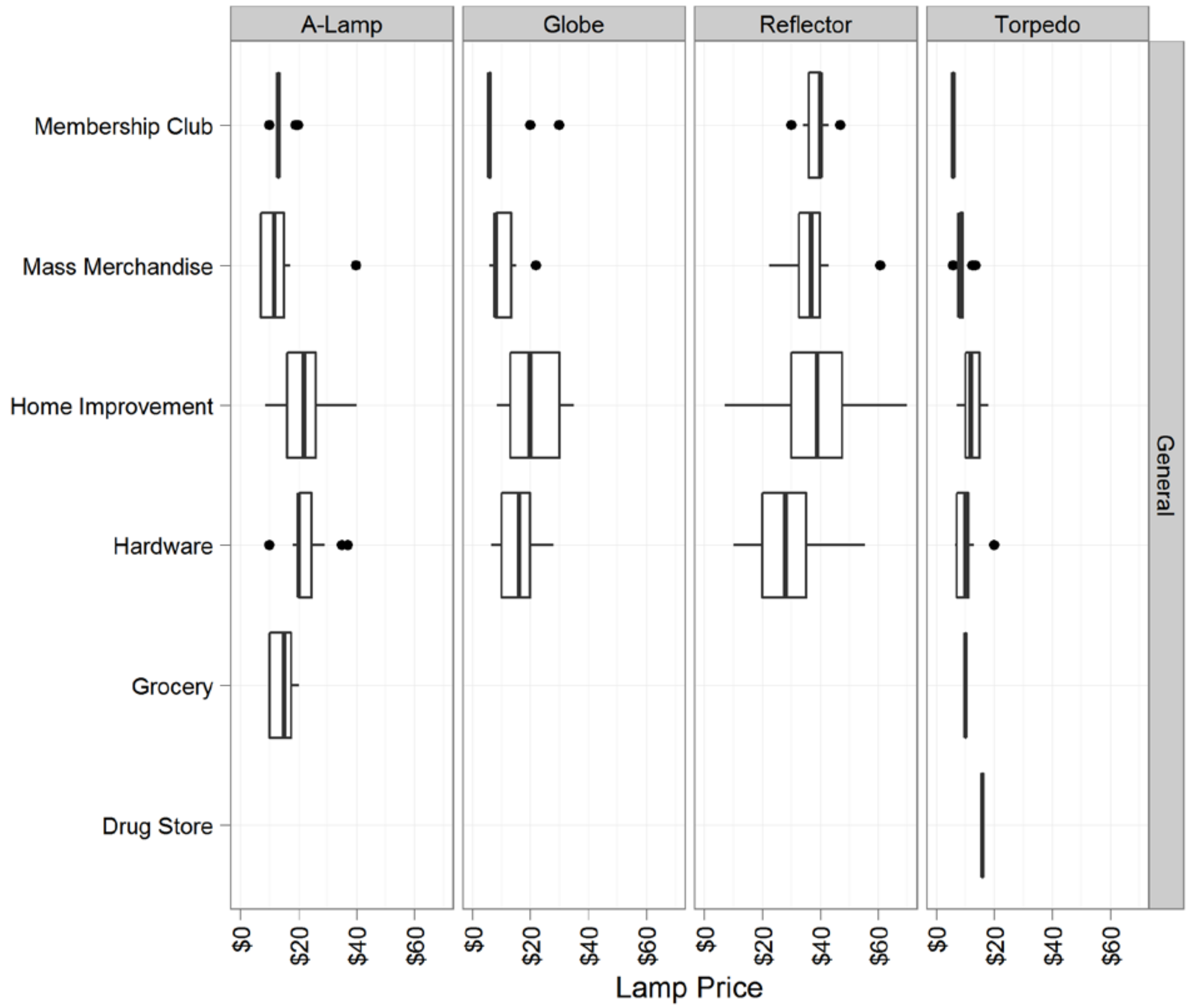
[2] However, LEDs require a special controller in a dimmable application. Controllers designed for incandescent bulbs vary power over a different range than what an LED bulb requires.

Figure 13 shows the relationship between LED lamp price and retail channel by lamp style and application. The shelf surveys did not record LED lamps in discount stores. As shown in Table 5, there are only three observations of LED lamps in drug stores. In addition, the surveys did not record reflector LED lamps, the most common style for LED lamps, in drug stores or grocery stores. The plot shows the following:

- The LED lamp price distribution varies considerably by retail channel. Home improvement stores tend to have the highest median price for general use lamps, excepting of torpedoes.
- The LED lamp price ranges vary by retail channel. Mass merchandise stores have smaller ranges than other channels while home improvement stores have bigger ranges.
- Some LED lamp price distributions are skewed. For example, the line showing the median price of a reflector at a membership clubs is near the upper quartile range.

The hedonic pricing model will need to account for differently styled distributions and LED lamp availability in each channel.

Figure 15 LED price distribution by retail channel, style, and application



shows the relationship between LED lamp wattage and price by lamp style and application. In contrast to the similar plots for incandescent and CFLs, the plot for LED lamps shows several clear patterns:

- The scatter plot shows a strong trend of LED lamp prices increasing with wattage.
- The wattage range for LED lamps is much smaller than that for CFLs and incandescent lamps.
- Each of the scatter plots shows a consistent slope.

The hedonic pricing model will explain lamp price as a linear function of wattage and other attributes. This plot presents evidence that the lamp wattage is a factor explaining lamp price.

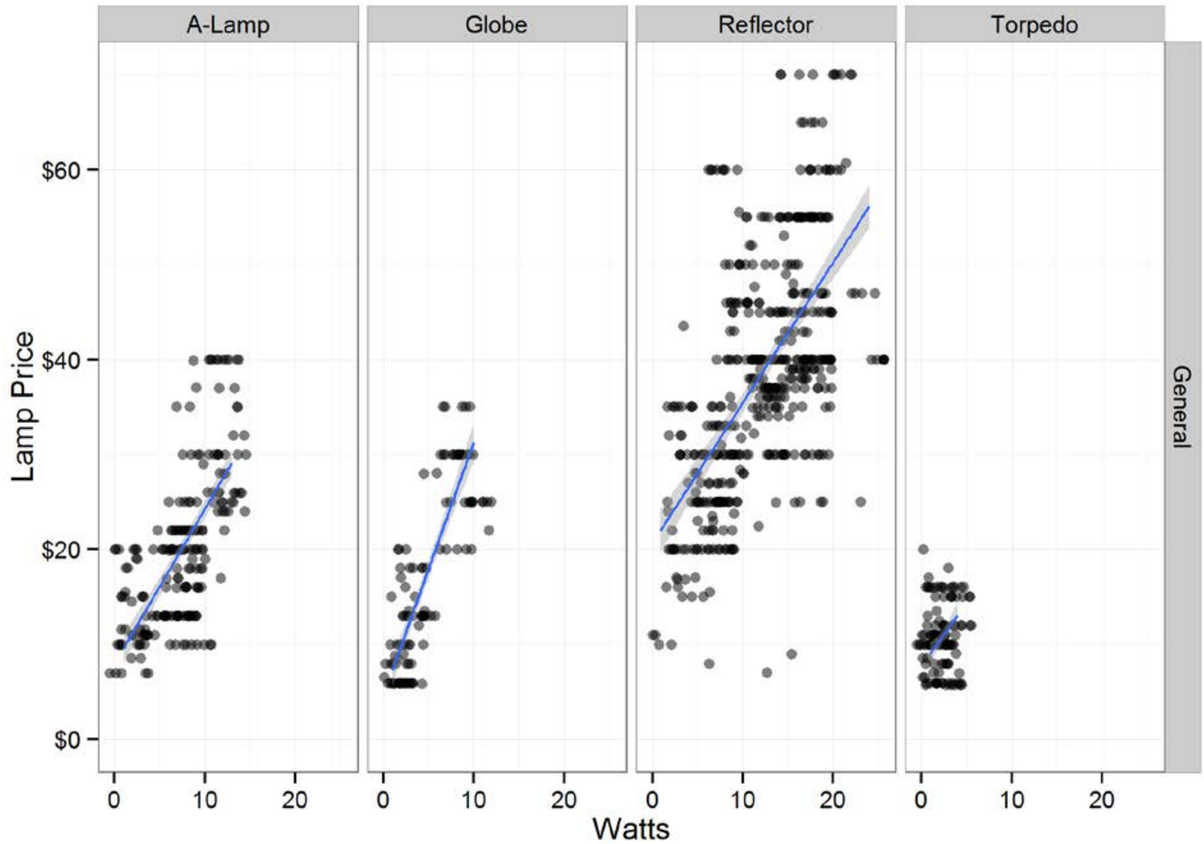


Figure 15 presents the relationship between the relationship between brightness measured in lumens and the lamp price by lamp style and application. The relationship is not as clear as the relationship between price and watts:

- The lumen domain for LED lamps is similar to incandescent and CFLs.
- Some of the LED lamp styles (e.g., reflectors) show evidence of a positive relationship between lumens and price.

While the hedonic pricing model may be able to use lumens to explain the lamp price, the visual evidence suggests that wattage will have more explanatory power. The model will not include both lumens and wattage directly as their correlation coefficient is 0.93.

Figure 16 LED price distribution by lumens, style, and application

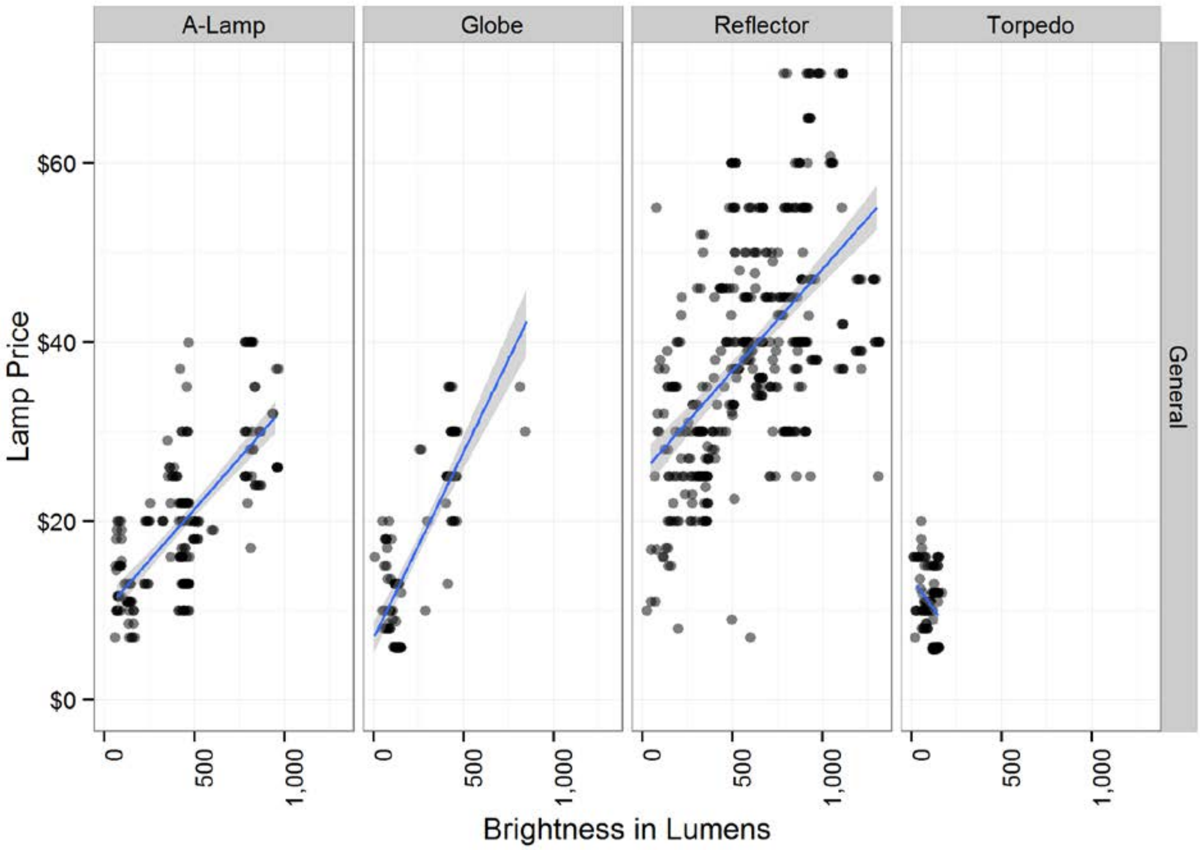
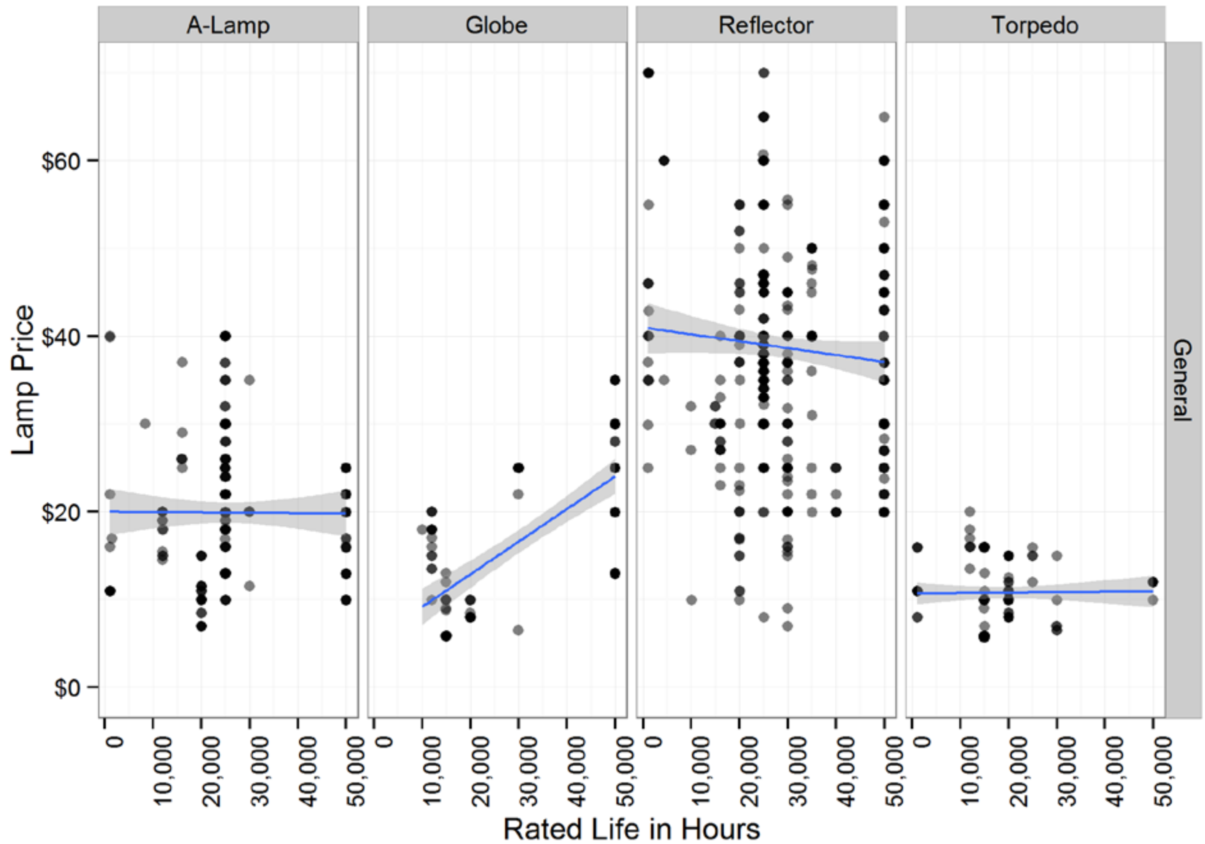


Figure 16 shows the relationship between rated life and lamp price by lamp style and application. LED lamps last many times longer than other lamp types—for example, incandescent lamps usually last less than 5,000 hours while comparable CFLs usually last less than 15,000 hours. The plot reveals the following:

- The rated life of an LED lamp has a large domain compared to incandescent and CFLs. The rated life ranges from near 1,000 to a few lamps with a rated life 50,000 hours.
- Except for torpedo styled lamps, LED lamp price tends to increase as the rated life increases.

The rated life appears to partially explain the price of an LED lamp. The hedonic pricing model should incorporate this variable.

Figure 17 LED lamp price distribution by rated life, style, and application



6. Next Steps

Combining the five shelf survey waves into one data set was an important milestone for this work order. The next two subtasks will make significant use of these data:

- **Subtask 3.2 –** Development of retail channel weights. Shelf surveys only quantify how many products are on display at a given point in time. Stocking information differs from lamp sales, which is what retail channel weights need to reflect. Although point of sale data is a more direct measurement of sales, not all retail channels are well-represented in the point of sale data, unlike the shelf surveys. The other source for retail channel weights is the supplier interviews. This source covers all of the retail channels, but is not a direct measurement. The program tracking data provide yet another data source for the channel weights. The challenge behind this subtask is to triangulate on a reasonable set of retail weights with objective data. The DNV KEMA team is in the process of assembling a companion technical memorandum that describes the data sources for retail channel weights.

- **Subtask 3.3 –** Estimation of hedonic price models. The results shown in section 5 of this memorandum suggest that there are relationships between wattage, lumens, retail channel, and the lamp style that will be useful for the pricing model. The estimation will also explore effects of other attributes (such as brand and Energy Star qualification) on price.

Appendix A. Shelf Survey Variables

Table 5presents the source of each of the variables in the combined dataset. The combined dataset includes five collection waves. The shelf survey instrument includes both store-level information as well as information for each package of lamps in the store.

Table 5 Combined shelf survey data layout

Description	Variables	Spring 2008	Fall 2008	SpringA 2009	SpringC 2009	Fall 2011
Store information						
Unique identifier for each store visited	store_id	store id	visit_id	visit_id	visit_id	store_id
Type of store retail channel	store_type	store type	store_type	store_type	retail_channel	store_type
Name of the store	store_name	store name	store_name	store_name	storename	store_name
Store's street address	store_address	store address	store_address	store_address	storestreeaddress	store_address
Store's city	store_city	store city	store_city	store_city	storecity	store_city
Store's zip code	store_zip	zip code	zip	zip	storezip	store_zip
Lamp information						
Unique identifier for each store visited	store_id	store id	visit_id	visit_id	visit_id	Store_id
Model number of Lamp	model_number	model number	model	model	modelnumber	Model_number_uc
Brand name of Lamp	brand	brand	manuf	manuf	manufacturer1	Brand_uc
Technology type of Lamp (CFL, Incandescent, LED)	bulb_type	bulb type	<created>	<created>	producttype	Product_Type_uc
Base type	base_type	n/a	n/a	n/a	basetype	Base_Type_uc
Lamp style or shape	bulb_style	n/a	style	style	bulbstyle	Bulb_style_uc
Total number of packages available in the store	total_pkg	n/a	num_pkg	n/a	num_packages	__of_Packages
Total number of Lamps available in the store	total_bulbs	n/a	n/a	n/a	nbr_bulbs	no_lamps
Number of Lamps in a pack	pkg_quantity	quantity in pack	qty	qty	quantity1	<created>
Full price per pack	pkg_price	price per pack (before discount/sale)	f_price for cfls i_price for incandescent	f_price for cfls i_price for incandescent	originalprice	Full_Price
Full price per Lamp	bulb_price	<created>	<created>	<created>	<created>	<created>

Description	Variables	Spring 2008	Fall 2008	SpringA 2009	SpringC 2009	Fall 2011
Discounted price per pack	pkg_discounted_price	price paid	d_price	<created>	finalprice	Discounted_Price
Discounted price per Lamp	bulb_discounted_price	price per bulb	<created>	<created>	price_per_bulb	Price_per_Bulb
Amount of discount per pack	pkg_discount	discount amount	disc_amt	disc_amt	<created>	<created>
Rated life in hours	bulb_hrs	n/a	n/a	n/a	ratelife	Rated_Life__hours_
Rated life in hours per day	bulb_hrs_day	n/a	n/a	n/a	n/a	Rated_Life_Hours_Day
Color temperature (in Kelvin)	bulb_color_temp	n/a	n/a	n/a	colortemp	Color_Temperature__Kelvin___K_
Color name	bulb_color	n/a	n/a	n/a	n/a	Color_uc
Lamp coating	bulb_coat	n/a	n/a	n/a	n/a	coat_uc
Lumens	bulb_lumens	n/a	lumens	lumens	lumens2	Lumens
Wattage	bulb_watts	wattage	watts	watts	wattage2	wattage_cl
Energy star indicator	bulb_estar	es label on package?	es	es	energystar	Energy_Star_
Dimmable indicator	bulb_dimmable	n/a	dim	dim	dimmable	Dimmable_
Three-way wattage indicator	bulb_3way	<created>	three	three	threeway	__way_wattage_flag
Advanced Lamp indicator	bulb_advanced	n/a	n/a	n/a	advanced_lamp	lampdesc
Wattage for three-way Lamps	bulb_3way_watts	<created>	_way_watts	_way_watts	n/a	__way_wattage
Lumens for three-way Lamps	bulb_3way_lumens	n/a	_way_lumens	_way_lumens	n/a	__way_lumen
EISA indicator	eisa	n/a	n/a	n/a	n/a	EISA_ComplianT_Flag

B.2 Technical Memorandum 2: Hedonic Regression Results

December 16, 2013

To	:	Katie Wu and Peter Lai Energy Division, California Public Utilities Commission
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Subject	:	**Technical Memorandum 2: Hedonic Regression Results**

1. Overview

The overall objective of Work Order 17 is to provide a framework for computing the incremental measure cost of replacing an incandescent lamp with a more efficient CFL or LED lamp or replacing a CFL with an LED. This memorandum reports on the results of the hedonic regression model[1]. The regression model is one of two principle inputs for calculating the incremental measure cost. The other principle input maps a lamp in one technology (i.e., incandescent, CFL, or LED) to an equivalent lamp in another technology.

The scope of these models is limited to medium screw base lamps. The scope includes incandescent (both traditional and EISA compliant), CFLs, and LED lamps in A-Lamp, Globe, Reflector, Torpedo, and Twister styles[2]. The models then explain variations in lamp prices as a combination of attributes such as the wattage, rated life, national brand, delivery channel, and other factors.

[1] Hedonic regression model treat the price of a good as a function of the attributes of that good.

[2] The results do not include tube style lamps. The Fall 2011 Shelf Survey included 16 complete observations of incandescent tubes. This sample size is too small to draw strong statistical conclusions on the price of incandescent tube lamps.

This memorandum builds on Technical Memorandum 1A. Memo 1A describes data from five shelf surveys. The shelf surveys record the price and attributes of lamps found in retail locations throughout California. This memorandum reports on models that use data from the Fall 2011 Shelf Survey.

The organization of this memorandum is as follows. Section 2 describes the variables in the model and gives a few general notes on the data. Section 3 presents the results for the incandescent, CFL, and LED models, respectively. Section 4 discusses some limitation of the hedonic price models. The memorandum concludes with a section describing the next steps.

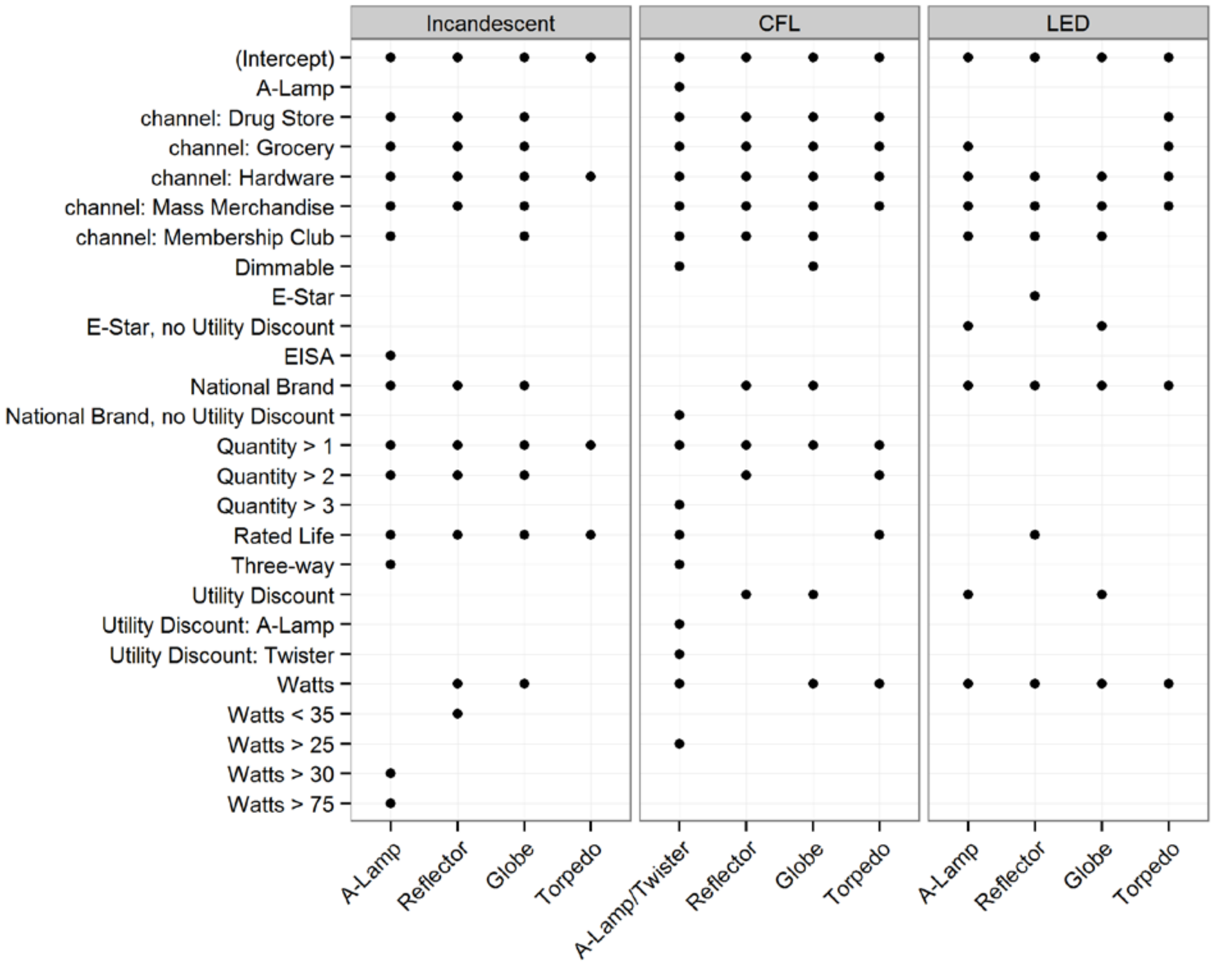
2. Description of Estimation Variables

This section describes the principle variables in the regression models. Figure 1 gives an overview of the shelf variables. Each dot denotes which variables a model for a specific technology and style include. The section also provides the rationale for including the variables. The models use the following variables:

- *Retail Channel Dummy Variables.* The price of lamps tends to vary by retail location. Drug stores, for example, tend to price lamps higher than other channels. The regression models include the retail channel as a dummy variable. The home improvement delivery channel is the reference level as this channel has the greatest selection of lamps. The model contains the following retail channels:
    - *Drug stores*
    - *Grocery*
    - *Hardware*
    - *Home improvement*
    - *Mass merchandise*
    - *Membership club*

  Note, that the models do *not* include the discount retail channel. Examples of stores in this channel include *The Dollar Store* and *99¢ Only*. As the names of these stores imply, there is little price variation in these channels. Model runs with a dummy for discount channel showed illogical results and implied negative prices under some conditions. As a result, DNV KEMA excluded discount channel observations from the estimation data and will document prices in the discount channel separately.

Figure 1 Variables in the Price Models



See section 5 for a discussion on how to incorporate discount channel weights into measure cost calculations.

- *Rated Life.* Manufacturers rate the life of each lamp in terms of hours of use. Most of the regressions use longer rated life to explain higher prices. For convenience, the models express life in units of thousands of hours.

- *Watts.* Lamp prices tend to increase with increases in watts. As the wattage increases, the material costs also increase. However the relationship is not always linear and there are sometimes offsetting factors. For example, there are relatively few lower wattage incandescent globes compared to higher wattage incandescent globes and many stores sell lower wattage globes at a higher price.

- *National Brand Dummy Variable.* Lamps with a nationally recognized brand tend to have higher prices than other brands. This dummy variable captures well-known brands that are not exclusive to a particular store. The national brands are: Feit, General Electric, Philips, Sylvania, and Westinghouse.

- *Dimmable Dummy Variable.* This variable captures CFLs that are designed for dimmable applications. Without special circuitry, CFLs will not work with a dimmable controller. Dimmable CFLs tend to cost more than standard CFLs.

- *Three-way Dummy Variable.* This variable captures lamps that work w*ith a three-way controll*er. Lamps designed for three-way controllers tend to cost more standard lamps.

3. Model Results

This section reports the final results from a series of regressions runs. The final regression results are the product of exploring many combinations of variables to explain the price of a lamp. The exploration relied on relationships described in Technical Memorandum 1A.

The final model forms are not the result of a applying a single criteria to each of the regression results. Rather, the final model form reflects the regression result that showed the greatest overall strength. The strength of a model follows from its ability to tell a concise, consistent, and compelling story.

- *Concise* models are able to explain the appropriate amount variation. There is a large amount of variation in lamp prices. For example, some incandescent A-Lamps cost over $10 whereas the median price is less than $2. The intention of lamp price models is to explain price variation for lamps with prices toward the middle of the price distribution. That is, explaining the prices of the most expensive and least expensive lamps is less important than explaining the average lamp price.

- *Consistent* models have coefficient values with logical relationships. For example, a model should say that the price per lamp decrease as the package size increases. Similarly, the higher the wattage on a lamp, the higher expected the price.

- *Compelling* models have a strong statistical fit. The probability that the coefficients are different than zero should be greater than 90%. Further, the overall model should account for a large amount of the price variation. The adjusted R^2 statistic captures how much of the price variation from the mean that the model explains. Values over 0.8 denote very a very strong statistical fit.

Models that have an adjusted R^2 is under 0.5 are not able to explain half the price variation. This may be due to unobserved attributes or features that influence the lamp price or a result of a limited number of observations.

The remainder of this section presents model results by lighting technology. Each subsection includes a table showing model results and a discussion. The "Coefficient" columns in the tables describe the variable, the "Estimate" columns give estimated coefficient value, and the "P-Value" column lists the statistical influence. P-values are an estimate of the probability that the differences found are due to chance, error, or bias. The study team generally considers p-values less than 0.10 to show a reasonable level of statistical influence.

3.1 Incandescent Lamps

Table 2 displays the results of the hedonic regression model for the four incandescent lamp styles. The overall fit of each of the models ranges from acceptable to a very strong level of statistical confidence. The adjusted R^2 value for reflectors, at 0.47, is somewhat below the desired level. This result suggests that the model may not include lamp attributes that are important to price. For example, the lamp shape and diameter may be important and missing variables that helps explain the price. The adjusted R^2 value for torpedoes (0.85) shows that the model effectively explains price variation.

Each of the models explains the price of a lamp using different combinations of lamp attributes. However, there are a few patterns across lamp styles:

- *Retail channel.* Drug, grocery, and hardware stores all have statistically higher lamp prices than stores in the home improvement channel[3]. The pricing differential between mass merchandise and membership clubs compared to home improvement stores is less clear. The coefficient on the mass merchandise retail channel is not consistently positive (indicating a higher price than in the home improvement channel). The mass merchandise channel has a negative coefficient for reflectors, although with a loose statistical certainty given the p-value of 0.20. The coefficient on membership clubs is not statistically different than home improvement for either A-Lamps or reflectors. All of these relationships match prior expectations.

- *Package size.* As the package size increases, the unit price for a lamp should decrease. There are two expectations for these variables. First, the sign should be negative. Second, the incremental discount should decrease as the quantity increases. That is, the incremental discount in moving from 1 to 2 lamps should be more than the incremental discount when moving from 2 to 3 lamps. In the model formulation, the two package-size variables are additive. Both the "2 or more" and

[3] In each of the models, the home improvement channel is the reference level. The choice of reference level is arbitrary as only relative differences between the retail channel dummy variables matter. The home improvement channel makes for a convenient reference level since the channel sells a greater variety of lamps than other channels.

the "3 or more" coefficient apply to lamps sold in a three pack. All the size coefficients are significant and match both expectations. The coefficient on "3 or more" did not yield a statistically significant result for torpedoes.

- *Three-way*. The coefficient on three-way lamps is $0.46 and $0.97 for A-Lamps and globes, respectively. The sign and magnitude of the coefficients matches expectations. There were not enough observations of three-way lamps in other styles to estimate coefficients.

- *National brand*. Lamps with a recognizable national brand tend to cost more than generic and store-specific brands. The coefficient values for A-Lamps and globes are similar at $0.84 and $0.64, respectively. The value for reflectors is somewhat higher at $1.58. The higher value is in part due to the generally higher prices of reflectors. Part of the higher value may be due to omitted variables specific to reflectors, such as the shape and diameter, which the model does not capture.

- *Rated life*. Lamps with a longer rated life tend to cost more as they are likely the result of a higher quality manufacturing process and higher quality material. The values on rated life (in thousands of hours) range from $0.20 to $0.59 on lamp styles where the rated life helps to explain the lamp price. The coefficient range seems reasonable. Rated life, however, did not help explain the price for globe lamps.

- *Watts*. The response between watts and price should be similar across lamp styles. The results in Table 2 confirm this expectation. Although wattage enters into each of models differently, the coefficient values across lamp styles (where watts are an explanatory variable) are nearly the same ($0.009 to $0.010). Globes have a dummy variable coefficient on watts under 35 to reflect the significantly lower price of these lamps.

  The model for A-Lamps includes watts as a spline variable to approximate the non-linear relationship between watts and price. Spline variables allow a linear model to approximate a non-linear response. In this model, the two watt coefficients ("watts over 30" and "watts over 70") are additive. The interpretation is that the price of an incandescent lamp begins to increase with watts when watts are greater than 30. The price continues to increase until reaching 70 watts. At this point, the total watt coefficient is the sum of the coefficient on "watts over 30" (0.009) and "watts over 70" (- 0.009). As the two coefficients sum to 0, further increases in watts do not change the price. As example, the effect of watts on price for a 75 watt lamp is: $(75 - 30) \times 0.009 + (75 - 70) \times (-0.009) = 0.36$.

Table 1 Incandescent Model Results

	A-Lamp		Reflector		Globe		Torpedo	
Coefficient	Estimate	P-Val	Estimate	P-Val	Estimate	P-Val	Estimate	P-Val
(Intercept)	2.132	0.000	3.984	0.000	2.465	0.000	3.724	0.000
Channel: Home Improvement								
Channel: Drug Store	0.990	0.000	2.604	0.000	0.904	0.000		
Channel: Grocery	0.250	0.002	0.892	0.004	0.151	0.195		
Channel: Hardware	0.418	0.000	1.477	0.000	0.506	0.000	0.295	0.004
Channel: Mass Merchandise	0.127	0.042	-0.181	0.200	0.228	0.005		
Channel: Membership Club	0.422	0.373	-1.098	0.474				
EISA compliant	0.334	0.000						
Package Size: 2 or more	-1.687	0.000	-2.324	0.000	-2.495	0.000	-2.549	0.000
Package Size: 3 or more	-1.155	0.000	-1.853	0.000	-1.456	0.000		
Three-way	0.462	0.000						
National Brand	0.834	0.000	1.574	0.000	0.638	0.000		
Rate Life (1000s of hours)	0.199	0.000	0.591	0.000			0.253	0.000
Watts			0.010	0.000	0.009	0.000		
Watts less than 35					-1.275	0.000		
Watts over 30	0.009	0.000						
Watts over 75	-0.009	0.001						
Adjusted R^2	0.58		0.47		0.62		0.85	
Degrees of Freedom	2932		2162		4268		137	

3.2 CFL Model Results

Table 3 shows the estimation results for CFL lamps. The overall fit of the CFL models is very good. The adjusted R^2 values range from 0.75 for A-Lamp/Twisters to 0.62 for torpedoes. Each of the models explains the unit price of a lamp as a function of a different combination of lamp attributes. There are, however, consistent patterns across all lamp styles:

- *Retail channels.* The drug, grocery, and hardware retail channels tend to price lamps higher than in the home improvement channel. Mass merchandise and membership club stores tend to price lamps lower than in the home improvement channel.

- *Package size.* The estimation results consistently show that retailers give quantity discounts and that the incremental discount decreases as the quantity increases.

- *National brands.* Retailers price CFL lamps with nationally recognized brands higher than generic or store-specific brands. The coefficient values for A-Lamp/Twisters ($1.12), reflectors ($1.08), and globes ($1.39) have similar and reasonable magnitudes. The A-Lamp/Twister model specifies national brand as an interactive effect with the absence of a utility discount. This mitigates the correlations with the utility discount variables described below.

- *Dimmable.* CFL lamps require special circuitry for use in dimmable applications. T his feature adds $5.81 and $4.05 to the price of A-Lamp/Twisters and reflectors, respectively. The data did not include examples of dimmable globes and torpedoes.

- *Watts.* The coefficients on watts range from $0.07 to $0.21. This band of coefficient values is reasonably narrow.
    - The model for A-Lamp/Twisters includes wattage as a spline variable. Lamps under 25 watts have a watt coefficient is $0.07; the coefficient is $0.16 otherwise. The model says that there is a higher incremental cost per watt for higher wattage lamps.
    - The globe model does not use watts to explain price variation. The data does not show a relationship between watts and price over the narrow range of globe wattage values.

- *Rated life.* The two styles (A-Lamp/Twister and torpedo) that include a coefficient on rated life have coefficients with similar magnitudes ($0.06 and $0.08).

- *Utility discounts.* The model estimation results show that utility discounts reduced average lamp prices by $3.04 and $1.26 for reflectors and globes, respectively. The A-Lamp/Twister model separates utility discount effects by style. As expected, the average discount is larger for A-Lamps ($3.52) than for twisters ($1.81). Note that all lamps eligible for utility discounts had to meet Energy Star program requirements

The A-Lamp/Twister model includes a dummy to distinguish A-Lamps from twisters. The only difference between CFL A-Lamps and twisters is the housing on A-Lamps that hides the CFL coils. The model represents the difference between the two styles by including a dummy variable on A-Lamps and constraining all other coefficients to be common across A-Lamps and twisters. The coefficient value of $1.84 is the average additional cost of an A-Lamp over an identical twister.

Table 2 CFL Model Results

Coefficient	A-Lamp or Twister Estimate	A-Lamp or Twister P-Val	Reflector Estimate	Reflector P-Val	Globe Estimate	Globe P-Val	Torpedo Estimate	Torpedo P-Val
(Intercept)	3.043	0.000	5.028	0	6.972	0.000	4.92	0
Style: A-Lamp	1.841	0.000						
Channel: Home Improvement								
Channel: Drug Store	1.219	0.000	2.738	0.000	0.984	0.001	1.750	0.000
Channel: Grocery	-0.375	0.009	0.639	0.093	0.059	0.909	1.433	0.091
Channel: Hardware	1.133	0.000	1.596	0.000	0.529	0.045	0.789	0.111
Channel: Mass Merchandise	-0.298	0.002	0.103	0.614	-1.524	0.000	-1.099	0.071
Channel: Membership Club	-1.019	0.000	-2.449	0.000	-3.471	0.000		
Package Size: 2 or more	-1.805	0.000	-2.794	0.000	-1.698	0.000	-2.008	0.000
Package Size: 3 or more					-0.629	0.083	-0.861	0.252
National Brand			1.075	0.000	1.388	0.000		
National Brand, no Utility Discount	1.115	0.000						
Dimmable	5.805	0.000	4.046	0.000				
Three-way	6.751	0.000						
Utility Discount			-3.040	0.000	-1.259	0.004		
Utility Discount: A-Lamp	-2.416	0.000						
Utility Discount: Twister	-3.515	0.000						
Rate Life (1000s of hours)	-1.804	0.000					0.077	0.072
Watts	0.062	0.000	0.147	0.000			0.206	0.010
Watts over 25	0.067	0.000						
Adjusted R^2	0.75		0.70		0.76		0.62	
Degrees of Freedom	2848		1008		281		97	

3.3 LED Results

Table 4 shows the estimation results for LED lamps. The overall fit of the LED models vary. The adjusted R^2 values range from 0.45 and 0.47 for torpedoes and reflectors, respectively, to 0.90 for globes. The lower values are marginally lower than the desired range. The low value for reflectors is consistent with the incandescent and CFL reflector models. Reflectors have attributes, such as shape and diameter, that are not part of the model. The low adjusted R^2 value for torpedoes may be in part due to the relatively small degrees of freedom (46) due to limited data points for this lamp type.

Each of the models explains the unit price of a lamp as a function of a different combination of lamp attributes. There are, however, consistent patterns across all lamp styles:

- *Retail channels.* Consistent with incandescent and CFL lamp technologies, the grocery and hardware retail channels tend to price lamps higher than in the home improvement channel. Mass merchandise and membership club stores tend to price lamps lower than in the home improvement channels. Note that the Fall 2011 Shelf Survey did not record any LED lamps in either the discount or drug store channels.

- *National brands.* Again, consistent with other lamp technologies, retailers price LED lamps with nationally recognized brands higher than generic or store-specific brands. The coefficient values for A-Lamp ($4.50), reflectors ($6.84), and globes ($6.64) all have similar and reasonable magnitudes.

- *Watts.* The coefficients on watts range from $1.41 to $2.97. This band of coefficient values is larger than for other technologies. This is partly due to the overall higher price of LED lamps.

- *Rated life.* The only style with a coefficient on rated life is the globe lamp. The model estimation results for other styles did not yield a statistically significant coefficient on rated life.

- *Utility discounts.* The mode estimation results show that the average discounts were $5.42 and $6.31 for A-Lamps and reflectors, respectively. Note that all lamps eligible for utility discounts had to meet Energy Star program requirements[4].

- *Energy Star label and no utility discount.* The Fall 2011 Shelf Survey recorded lamps labeled as Energy Star compliant but did not have a utility discount. The theory behind the label is that it should encourage consumers to buy approved products as these products will save money and energy over time. The coefficients on this variable are all positive and significant for lamp styles with Energy Star labeled lamps.

Note that during the Fall 2011 Shelf Survey data collection period, retailers did not offer LED lamps in multi-packs. As such, there was not enough information to estimate quantity discount effects.

[4] SCE and PG&E discounted some LED lamps as part of a pricing study.

Table 3 LED Model Results

	A-Lamp		Reflector		Globe		Torpedo	
Coefficient	Estimate	P-Val	Estimate	P-Val	Estimate	P-Val	Estimate	P-Val
(Intercept)	1.981	0.082	16.594	0.000	2.337	0.025	1.863	0.469
Channel: Grocery	2.426	0.101					-0.485	0.696
Channel: Hardware	8.304	0.000	2.856	0.077	4.878	0.000	3.198	0.008
Channel: Mass Merchandise	-0.053	0.966	-6.377	0.022	-4.704	0.000	-1.417	0.165
Channel: Membership Club	-8.309	0.000	-12.398	0.000	-3.577	0.000		
National Brand	4.505	0.000	6.839	0.000	6.644	0.000	5.045	0.003
Utility Discount	-5.559	0.031	-6.337	0.001				
Energy Star and no Utility Discount	2.372	0.012	7.608	0.000	3.970	0.085		
Rate Life (1000s of hours)					0.074	0.010		
Watts	2.042	0.000	1.406	0.000	2.302	0.000	2.972	0.000
Adjusted R^2	0.75		0.47		0.90		0.45	
Degrees of Freedom	191		408		96		46	

4. Model limitations

Although the all models are able to explain price variation, there are a few limitations that were not explored completely due to project scope and budget factors. These limitations include:

- *Possibility of negative prices.* Modeling the price of low-priced lamps with a strictly linear model is difficult. Certain product attribute combination could result in a negative price, which is, of course, a non-plausible outcome. Two modeling strategies to overcome this issue include:
  - *Log-linear models.* These models explain the natural log of price as a function of product attributes. A one unit change in a product attribute results in a percentage change in the price. The advantage of this approach is that the specification is easy to interpret. However, model specification does impose a relationship between the
  - *Tobit models.* These models censor results. The effect for a price model is that the model form can set a lower bound prediction. That is, the price is guaranteed to be positive.

- *Non-linearity in watts.* The relationship between price and watts is not linear for the incandescent and CFL lamps. The models use spline variables to approximate the relationships. A more robust approach is to use non-linear estimation techniques. Non-linear techniques mitigate the criticism that spline variables cause an abrupt change at arbitrary points.

- *Geographic effects.* The Fall 2011 Shelf Survey sample design was not randomly distributed with respect to geographies. Thus, the models have a potential for geographic bias. DNV KEMA constructed a simple test to detect the bias:

    1. Map each store location to county.

    2. Let the county enter the model as dummy variables.

    3. Apply an F-test to see if the group of county dummy variables to see if there is evidence that this group of variables explains price.

    The F-test showed that the county dummies do add explanatory power. The implication is that geography explains price and that models without geography suffer from an omitted variable bias.

5. Next Steps

The hedonic regression models are one part of calculating the incremental measure cost. Computing the incremental measure costs consists of the following steps:

1. Matching an efficient lamp with a less efficient baseline. DNV KEMA has prepared equivalency tables that map lamps by lumen range and style across technologies. For example, the table pairs a 60 watt incandescent with the equivalent CFL and LED options.

2. Computing the full measure cost for the efficient and the baseline lamp, by retail channel. The hedonic price model provides the price computation formula..

3. Compute the overall full measure costs for the efficient and the baseline lamps using retail channel sales weights to combine the retail channel-specific results from step 2.

4. Compute the incremental measure cost as the full measure cost of the efficient lamp minus the full measure cost of the baseline lamp.

DNV KEMA will describe the equivalency table mentioned in step 1 in the forthcoming Technical Memorandum 3. DNV KEMA is currently working on the sales weights as part of Work Order 28. We will document the sales weights in Technical Memorandum 4.

B.3 Technical Memorandum 3: Lamp Grouping, Lumen Ranges, and Wattage to Lumen Equivalencies

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Subject	:	**Technical Memorandum 3: Lamp Grouping, Lumen Ranges, and Wattage to Lumen Equivalencies**

1. Overview

The overall objective of Work Order 17 is to provide a framework for computing the incremental measure cost of replacing an incandescent lamp with a more efficient CFL or LED lamp or replacing a CFL with an LED. The purpose of this memorandum is to explain how to translate the brightness of lamp in one technology thein the absence of . This lamp grouping and lumen—wattage equivalency one of two principle inputs for calculating the incremental measure cost. The other principle input maps a lamp in one technology (i.e., incandescent, CFL, or LED) to an equivalent lamp in another technology.

Replacement lamps included in study are limited to medium screw base CFL, LED, and incandescent replacement lamps. Incandescent lamp technologies are further broken into EISA[1]-compliant lamps and those lamps that do not comply with EISA regulations.[2] Lamp styles included in this study are A-lamps, twisters (for CFLs only), reflectors, and globes.

We provide further details on lamp groupings, lumen ranges, and wattage to lumen equivalencies in the sections below.

[1] The Energy Independence and Security Act (EISA) of 2007 mandates higher energy efficiency standards for general purpose incandescent and halogen lamps. For further details on the legislation, please visit: http://www.govtrack.us/congress/bills/110/hr6

[2] In this memorandum, we refer to EISA-compliant lamps as "EISA incandescents" and EISA non-compliant lamps as "traditional incandescents."

2. Lamp Groupings

Table 1, below, shows watt ranges by brightness categories and lamp types. The general purpose category includes A-lamp CFLs, twister CFLs, A-lamp incandescents (both traditional and EISA incandescents), and A-lamp LEDs. Since EISA regulations mandate standards for general purpose lamps, we create a distinction between traditional incandescents and EISA incandescents in the general purpose category only.[3] All of categories also take into account the functional relationship between CFLs, incandescents, and LEDs.

3. Lumen Ranges

The lumen ranges (see Table 1 below) are designed to capture at least three categories of brightness. The general purpose category has four levels of brightness: low (60-699 lumens), medium (700-1199 lumens), high (1200-2099 lumens), and very high brightness (2099 or greater lumens) The reflector and globe categories have three levels of brightness: low, medium, and high (with the same lumen ranges listed for the general purpose category).

The brightness categories created for this study are based on lumen ranges observed in DNV KEMA lighting retailer shelf survey data collected by field researchers in hundreds of stores across California in seven retail channels (discount, drug, grocery, hardware, home improvement, mass merchandise, and membership club stores). The breaks between brightness categories take into account typical lumen ranges found for different lamp technologies and lamp styles. The general purpose lamp category shows the greatest variation with respect to lumen ranges across different lamp technologies. For example, twister CFLs, A-lamp CFLs, A-lamp traditional incandescents, and A-lamp EISA incandescents exist in low, medium, and high brightness categories. A-lamp LEDs can be found in low and medium brightness. And since twister CFLs and A-lamp traditional incandescents were observed with 2100 or more lumens, we created a very high brightness lumen range for the general purpose lamp category to account for these lamps. Only incandescents were observed having 2100 lumens or more in the reflector and globe lamp groupings. We did not include a very high brightness range for those lamp categories as there are few CFL or LED equivalents.

4. Wattage to Lumen Equivalences

We developed wattage range to lumen range equivalences in order to place a given lamp in the appropriate lumen bin if we encountered a lamp package that did not list lumens during a retail shelf survey. These wattage ranges are based on lamp packages observed in shelf surveys that listed both wattage and lumens, and take into account the typical distribution of lumens for a given wattage range. Thus, we would

[3] Although globe style incandescents are not regulated by EISA, some incandescent reflector lamps are regulated. Due to the complexities of the efficiency requirements for reflector incandescent lamps (which include numerous exemptions), we have not broken out EISA-compliant reflector incandescent lamps from EISA-non-compliant incandescent reflector lamps in our lamp groupings.

consider a 9 watt twister CFL, a 9 watt A-lamp CFL, a 40 watt traditional incandescent, a 29 watt EISA incandescent, and a 9 watt A-lamp LED to be low brightness since there typical light output for these lamps is below 700 lumens. Similarly, a 13 watt twister CFL, a 13 watt A-lamp CFL, a 60 watt traditional incandescent, a 43 watt EISA incandescent, and a 13 watt A-lamp LED would be considered medium brightness because the typical light output for these bulbs is between 700 and 900 lumens.

It should be noted that wattage equivalencies can vary by lamp style. For example, reflector and globe CFLs tend to be slightly less efficient than twister CFLs. Furthermore some lamps that are identical in technology and style may be less efficient or more efficient than a similar lamp with the same wattage. Traditional A-lamp incandescents, in particular, show a high degree of variation with respect to efficiency.

Table 1 Lumen groupings and wattage equivalents by lamp style

Lamp Style	Watts				
	CFL Twister or General	CFL A-Lamp	Incandescent (Traditional)	Incandescent EISA	LED
General Purpose (A-Lamps & Twisters)					
Very High Brightness (>2099 lm)	> 30		> 150		
High Brightness (1200-2099 lm)	18 - 30		76 - 150	70 - 72	
Medium Brightness (700-1199 lm)	12 - 17	13 - 17	50 - 75	43 - 69	12 - 13
Low Brightness (60-699 lm)	4 - 11	5 - 11	11 - 49	28 - 42	1 - 11
Reflector					
High Brightness (1200-2099 lm)	20 - 30		76 - 150		18 - 24
Medium Brightness (700-1199 lm)	14 - 19		50 - 75		13 - 17
Low Brightness (60-699 lm)	5 - 13		12 - 49		1.7 - 12
Globe					
High Brightness (1200-2099 lm)			76 - 150		
Medium Brightness (700-1199 lm)	14 - 20		50 - 75		
Low Brightness (60-699 lm)	7 - 13		25 - 49		1.3 - 10
Torpedoes					
Medium Brightness (700-1199 lm)	14 - 17		50 - 75		
Low Brightness (60-699 lm)	5 - 13		25 - 49		1.2 - 5

B.4 Interim Retail Channel Sales Weight

December 16, 2013

To	:	Katie Wu and Carmen Best Energy Division, California Public Utilities Commission
From	:	Andrew Stryker DNV KEMA Energy & Sustainability
CC	:	Fred Coito and Kathleen Gaffney DNV KEMA Energy & Sustainability Mike Ting Itron
Subject	:	**Interim retail channel sales weight**

Residential lighting studies rely on the concept of retail sales channels. The channels have a common price and product availability structure and attract different consumer demographic groups. Retail channels are a useful tool for explaining the price variation of lamps and the purchasing decisions of consumers. For example, the analysis for the measure cost study produced separate incremental costs for each retail channel. The overall average incremental measure cost is the weighted sum the incremental measure by retail channel over all of the retail channels. The weights measure the relative sales volume of each retail channel.

This memorandum serves as documentation of the interim retail channel sales weights. We expect final weights to be available in about 6 weeks. The memorandum defines the retail channels, lists the data sources, and documents sales weight estimation by channel. The retail channel weights in this draft are interim weights as they do not reflect the full scope of the data collected for the residential lighting evaluation.

1. Retail Channel Definitions

Retail channels included in this research are defined as follows:

- **Discount** – Retail stores that sell a wide variety of products at a deep discount. Many items typically sell for $1 or less. These stores do not feature food/groceries as their primary product. Examples include: 99 Cents Only, Dollar Tree, and Big Lots.

- **Drug** – Retail stores that feature prescription and over the counter drugs as well as a wide variety of other products. Examples include: CVS, Rite Aid, and Walgreens.

- **Grocery –** Retail stores that feature food/groceries and/or liquor as their primary product. The shelf surveys include stores from three grocery channel sub-categories:
  - *Large grocery stores* are national or regional chains that do not feature food and other products at a deep discount. They also typically sell both utility discounted and non-discounted light lamps. Examples include: Albertsons, Ralphs, and Safeway/Vons.
  - *Independent grocery stores* are almost always independently owned and typically have up to nine locations in a small geographic area. Independent grocery stores usually only sell utility discounted light lamps. Examples of independent grocery stores include Draegers Market, Laurel Street Grocery, and Spencer’s Fresh Markets.
  - *Discount grocery stores* are usually larger chains that feature food and other products at a deep discount. Discount grocery stores usually only sell utility discounted light lamps. Examples of discount grocery stores include Grocery Outlet and Smart and Final.
- **Hardware –** Retail stores that feature hardware as their primary product. Hardware stores are typically independently owned (including hardware stores with national affiliations, such as Ace and True Value). Also included in this category are independently owned lumber stores that feature a small variety of light lamps. Examples include Ace Hardware, True Value Hardware, Chino Lumber and Hardware, and Foothill Hardware.
- **Home Improvement –** Large retail stores that feature home improvement merchandise as their primary product. These stores are typically large national or regional chains. Examples include Home Depot, Lowe’s, Orchard Supply Hardware, and HD Supply.
- **Mass Merchandise –** Large retail stores that offer a very wide range of products, including clothing, appliances, electronics, and furniture. All mass merchandise stores are large national or regional chains. Examples include Wal-Mart, Target, IKEA, and Kmart.
- **Membership Club –** Large retail stores that offer a wide array of products, including food, clothing, electronics, and furniture. Many items sold at membership club stores are sold in bulk and at discounted prices. These stores require customers to purchase annual/semi-annual memberships in order to buy merchandise. All membership club stores are large national or regional chains. Examples include Costco and Sam’s Club.

Other channels, such as lighting showrooms, electronics stores and online retailers, are not included in this study at this time.

2. Data Sources

There are five primary data sources that can serve as basis for estimating retail channel sales weights:

- **Supplier interviews–**DNV KEMA has conducted hundreds of in-depth interviews with lighting suppliers – i.e., manufacturers, lighting buyers, large, national chain retailer sales representatives, and retail store managers. The results from these interviews have been used since 2004 to estimate total CFL sales by retail channel, including estimates of sales within and outside of IOU programs. The supplier interview data provide a comprehensive estimate of retail channel sales although they do not precisely measure sales.

- **Point of Sale (POS) records–**These data record the price and quantity of lamps at the time of sale. Itron has collected POS data since the late 1990s. The most recent data are for 2010 and 2011. The most recent POS data purchased by Itron covers lighting sales through drug stores, grocery stores, small hardware stores, and some big box retail stores. In the past, Itron has attempted to identify products discounted through the IOU upstream lighting programs although there is no flag in the POS databases that isolates within program versus outside program sales. This data source is a direct measurement of the retail sales.

- **Program tracking data–**The IOUs provide information on all products discounted through the upstream lighting program. This includes model number, manufacturer, retailer, product style, wattage and lumens, and rebate and pricing information. DNV KEMA has access to program tracking data from as far back as 2004. This data source is a comprehensive and relatively direct measurement of lamps sold through IOU programs.

- **Intercept surveys**—DNV KEMA has conducted thousands of customer intercept surveys throughout California. The field staff attempted to interview all consumers who had lamps in their shopping baskets at the time of the intercept. The intercept surveys are not a representative sample.

- **Shelf surveys–**The shelf surveys record detailed product information on each lamp in a store. The survey includes the number of packages present, price, brand and model number, and lamp technology and style. This data source comprehensively measures inventory rather than sales.

Table 1 compares each of the data sources to show differences in coverage and collection methods. None of the data sources listed above directly measure the sales of all lamps across all retail channels. The challenge of developing sales weights is in how to combine different data sources into a global picture of sales by retail channel.

Table 1 Data source summary

	Supplier Interviews	Point of Sales	Program Tracking	Shelf Surveys	Intercept Surveys
Retail channels	All	Drug, Grocery, and Hardware only	All	All	All
Lamp technologies	CFL	CFL	CFL and LED	All	All
Measurement method	Self-reported estimates from major suppliers	Sales transactions	Program shipment transactions	Field research in a sample of stores	Field research in a sample of stores
Other limitations			Only program lamps	Measurement of stock, not sales	Opportunistic sampling

3. Weights by Channel

DNV KEMA has explored two tracks for developing sales weights. The first track uses the intercept survey response rates. The second track uses program tracking and supplier interviews. The second is not complete as DNV KEMA is currently tabulating the supplier interviews. In both cases, we group the retail channel sales weights into to two lamp types: basic and advanced. The basic category includes A-Lamp shaped incandescent and Twister shaped CFL lamps. The advanced category includes all other lamps. The shelf survey data are useful for splitting the basic and advanced product categories into lamp styles, i.e. A-Lamps, Twisters, Reflectors, Globes, and Torpedoes.

3.1 Intercept survey approach

The intercept surveys are the only basis for the incandescent and LED retail channel sales weights. The program tracking data and the supplier interviews contain no information about incandescent lamps and little information about LED lamps. The primary shortcoming of this approach is the lack of a representative sample. The respondents in the intercept surveys are not the result of random sample of stores and a random sample of customers in those stores. Mostly due to the difficulties in gaining access to retail locations, the sampling plan for retail stores is better described as opportunistic. Similarly, the sample of customers is opportunistic. Although we attempted to interview every customer making a lamp purchase, we expect that the response rates vary across demographics.

Table 2 shows the weights DNV KEMA developed using this approach. The weights are the result of the following process:

1. Sum the number of lamps by retail channel and lamp type (basic/advanced).

2. Sum the number of hours that field researchers spent in each store by retail channel.

3. For each retail channel, divide the total lamps in step 1 by the total hours in step 2. This is a normalization step that accounts for the field staff not spending equal time in each retail channel. The result of this step is the number of lamps per hour by retail channel and lamp type.

4. Compute the weights in each channel as the lamps per hour in the channel over the lamps per hour summed across the retail channels.

Table 2 Retail channel sales weights using the intercept survey approach

	Incandescent		CFL		LED	
	Basic	Advanced	Basic	Advanced	Basic	Advanced
Discount	20%	0%	4%	6%	-	0%
Drug Store	3%	6%	2%	9%	-	0%
Grocery	17%	29%	21%	20%	-	0%
Hardware	14%	23%	18%	11%	-	0%
Home Improvement	13%	4%	15%	23%	-	48%
Mass Merchandise	33%	37%	30%	18%	-	0%
Membership Club	0%	1%	9%	14%	-	52%

DNV KEMA is currently developing respondent and storefront weights to address these shortcomings of the initial calculation. Respondent weights will make the demographic distribution of the intercept survey sample match that of the population by store. Given a representative demographic distribution by store, we will be able to expand to the channel level using storefront weights that are being developed under Work Order 13, a different part of the CPUC 2010-2012 evaluation. The storefront weights will allow us to estimate an overall sales volume and weights for each retail channel.

3.2 Program tracking and supplier interviewer approach

An alternative approach is to begin with the program tracking data. These are transactional data that record program product shipments. As they only record program activity, these data do not give a complete picture of lamp sales within each retail channel. The supplier interviews contain retailer estimates of program and non-program activity within each of the stores. Combining these data sources leads to estimates of total lamp sales by retail channel.

The details of this approach are as follows:

1. Use the programing tracking data as the measurement of program sales.
2. Use the supplier interviews with retailers to estimate the split between program and non-program sales.
3. Estimate the total sales by retail channel and lamp type using the results of steps 1 and 2.
4. Compute the weights in each channel as the estimated lamp sales in the channel over the lamp sales summed across the retail channels.
5. Adjust the weights for the drug store, grocery, and hardware channels to match the point-of-sales data. The point-of-sales data are a direct measurement of total CFL lamp sales in these channels.

DNV KEMA is currently processing the retailer interviews for the current evaluation program cycle. When this is complete, we will update the sales weights to reflect the most recent shelf-report information.

3.3 Allocation to lamp styles

The two approaches outlined above produce estimates of retail channel sales weights for basic and advanced lamp products. For some applications, we need to split the basic and advanced categories into lamp styles. The shelf surveys capture the product stocking mix within each retail channel. These data show which retail channels stock which lamp styles.

Figure 1 shows product availability from the Fall 2011 shelf survey. The Fall 2011 shelf survey is the data source for the measure cost study. The plot shows lamp availability by lamp style and lamp technology within each retail channel. The plots show the number of survey retail stores in a channel carrying a product through the size of dot. Blue dots indicate that DNV KEMA found over five stores within a retail channel carrying lamps in a category.

Figure 1 Product availability during Fall 2011

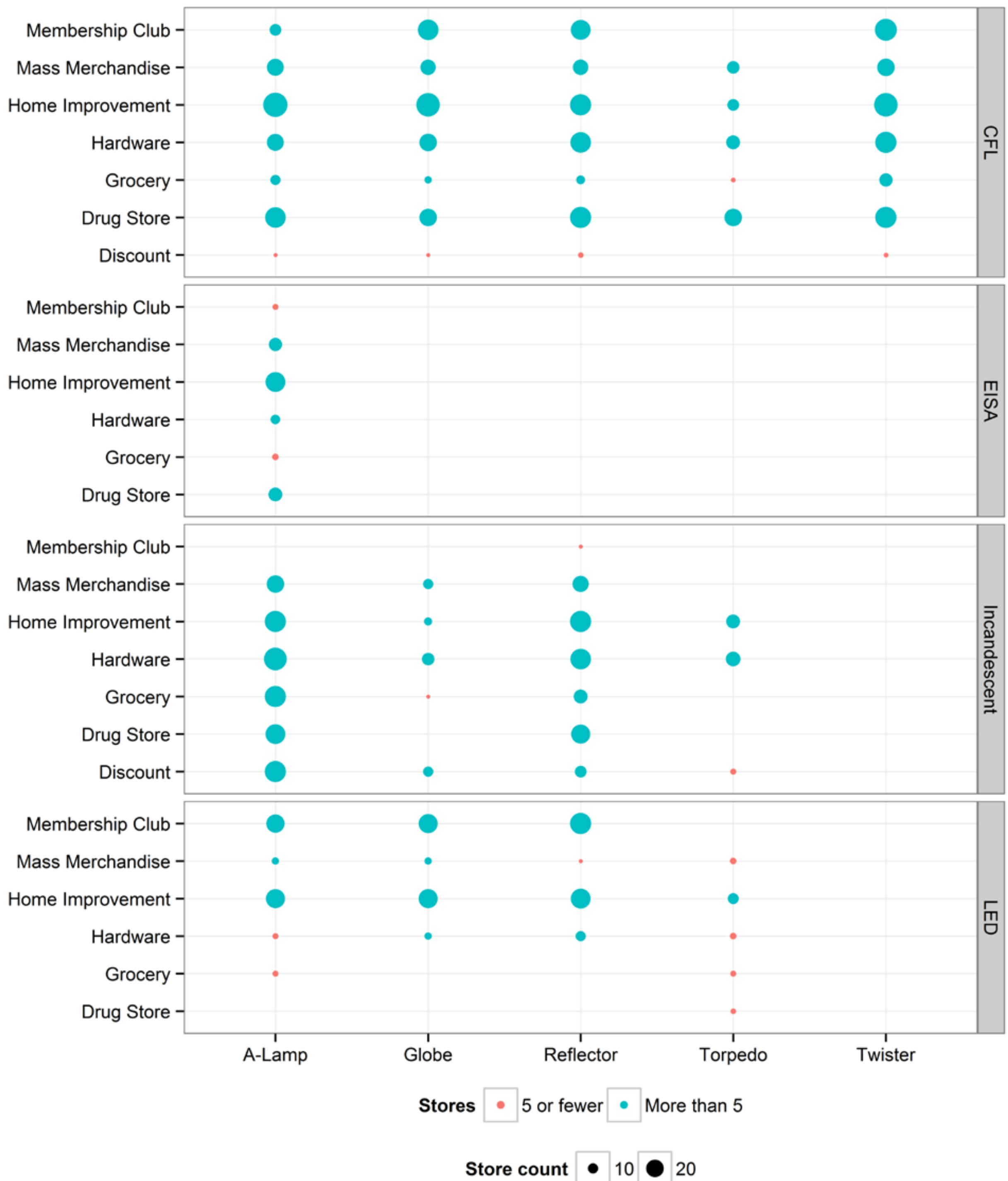


Table 3, Table 4, and Table 5 show the interim retail channel sales weights for incandescent, CFL, and LED lamps, respectively. The process for allocating the weights by basic and advanced in Table 2 is as follows:

1. Map basic and advanced lamps to lamp styles. The basic lamp category includes incandescent A-Lamps and CFL Twisters. All other lamp types are in the advanced category.

2. Zero the weights where the number of stores selling the lamp is 5 or less. This threshold represents a minimal level of observed activity. The one exception to this rule is CFL Twisters in discount channel stores. The program tracking data shows that CFL Twisters are sold through this channel in greater numbers than the shelf surveys suggest.

3. Rescale the weights to sum to 100% across retails by lamp technology and style.

Table 3 Intermin incandescent retail channel sales weights

	A-Lamp	Globe	Reflector	Torpedo
Discount	20%	0%	0%	0%
Drug Store	3%	0%	6%	0%
Grocery	17%	0%	29%	0%
Hardware	14%	36%	23%	84%
Home Improvement	13%	7%	4%	16%
Mass Merchandise	33%	58%	37%	0%
Membership Club	0%	0%	0%	0%

Table 4 Intermin CFL retail channel sales weights

	A-Lamp	Globe	Reflector	Torpedo	Twister
Discount	0%	0%	0%	0%	4%
Drug Store	10%	10%	10%	15%	2%
Grocery	21%	21%	21%	0%	21%
Hardware	11%	11%	11%	17%	18%
Home Improvement	24%	24%	24%	38%	15%
Mass Merchandise	19%	19%	19%	30%	30%
Membership Club	15%	15%	15%	0%	9%

Table 5 Intermin LED retail channel sales weights

	A-Lamp	Globe	Reflector	Torpedo
Discount	0%	0%	0%	0%
Drug Store	0%	0%	0%	0%
Grocery	0%	0%	0%	0%
Hardware	0%	0%	0%	0%
Home Improvement	48%	48%	48%	100%
Mass Merchandise	0%	0%	0%	0%
Membership Club	52%	52%	52%	0%

Appendix C

VACOM Summary Report – Commercial and Industrial Refrigeration Measures

DEER Measure Cost Study

Summary Report

Prepared by

VaCom Technologies

San Luis Obispo, California

November 25, 2013

Contents

Summary

The Database for Energy Efficient Resources (DEER) provides estimates of the energy-savings potential and projected costs for energy efficiency measures (EEMs) in residential and nonresidential applications. Updates to the DEER have been developed by the California Public Utilities Commission (CPUC) with funding provided by California ratepayers. This report includes current cost estimates for select EEMs in the commercial and industrial refrigeration sector. Costs were estimated for the following EEMs:

- Walk-in box door closers
- Retrofit Glass Doors on Open Medium-Temperature Refrigerated Display Cases
- Replace Open Medium-Temperature Display Cases with New Cases with Reach-In Doors
- Evaporator Fan Controls
- Floating Suction Pressure
- Floating Head Pressure
- High-Efficiency Fan Motors on Walk-Ins and Display Cases

In addition, the following measures are proposed for inclusion in the DEER:

- Walk-in box door closers, for doors greater than 42” wide
- Strip curtains on walk-in box doors
- Evaporator Fan Controls for Motors >1 HP and/or >460 Volts
- LED Display Case Lights

A summary of the EEM costs for each measure are presented in the tables below:

Summary Table - Commercial Measures

Measure ID	Measure Description	Base of Measure	Cost Units	Equipment Cost (per unit)	Labor Cost (per unit)	Installed Cost (per unit)	Notes
D03-202	High-efficiency walk-in fan motors	retrofit	$/motor	$226.20	$42.81	$269.01	
D03-203	High-efficiency door display case fan motors	retrofit	$/motor	$122.41	$18.30	$140.71	
D03-203	High-efficiency open display case fan motors	retrofit	$/motor	$122.41	$19.29	$141.70	
D03-206	Medium Temp Glass Doors	retrofit	$/ft of case	$320.84	$176.98	$497.82	
D03-207	New Med. Temp Display Case with Doors	retrofit	$/ft of case	$686.29	$322.38	$1,008.67	
D03-208	Auto-closers on Main Cooler Doors, under 42" wide	retrofit	$/door	$155.67	$70.78	$226.45	
TBD	Auto-closers on Main Cooler Doors, over 42" wide	retrofit	$/door	$917.19	$140.36	$1,057.55	
D03-209	Auto-closers on Main Freezer Doors, under 42" wide	retrofit	$/door	$155.67	$70.78	$226.45	
TBD	Auto-closers on Main Freezer Doors, over 42" wide	retrofit	$/door	$917.19	$140.36	$1,057.55	
D03-210	Evaporator Fan Control on Walk-in Coolers & Freezers, <1 HP	new	$/motor	$0.00	$0.00	$0.00	Standard Offering from Multiple Mfrs
D03-210	Evaporator Fan Control on Walk-in Coolers & Freezers, <1 HP	retrofit	$/motor	$420.95	$199.55	$620.50	
TBD	Evaporator Fan Control on Walk-in Coolers & Freezers, >1 HP	new	$/motor	$1,212.12	$762.14	$1,974.26	
TBD	Evaporator Fan Control on Walk-in Coolers & Freezers >1 HP	retrofit	$/motor	$762.14	$762.14	$1,974.26	
D03-220	Floating Suction Pressure	new	$/Suct. Grp.	$0.00	$0.00	$0.00	Required per T24. Scope limited to retrofit on workpapers
D03-220	Floating Suction Pressure	retrofit	$/Suct. Grp.	$6,210.30	$7,944.02	$14,154.32	
D03-221	Floating Head Pressure (FHP), Fixed Setpoint (air-cooled)	new	$/Discharge Grp	$0.00	$0.00	$0.00	Required per T24. Scope limited to retrofit on workpapers
D03-221	Floating Head Pressure (FHP), Fixed Setpoint (air-cooled)	retrofit	$/Discharge Grp	$4,008.68	$4,673.43	$8,682.11	
D03-222	FHP, Fixed Setpoint (evap-cooled)	new	$/Discharge Grp	$0.00	$0.00	$0.00	Required per T24. Scope limited to retrofit on workpapers
D03-222	FHP, Fixed Setpoint (evap-cooled)	retrofit	$/Discharge Grp	$4,008.68	$4,673.43	$8,682.11	
D03-223	FHP, Variable Setpoint (air-cooled)	new	$/Discharge Grp	$0.00	$0.00	$0.00	Required per T24. Scope limited to retrofit on workpapers
D03-223	FHP, Variable Setpoint (air-cooled)	retrofit	$/Discharge Grp	$4,406.24	$4,882.31	$9,288.55	
D03-224	FHP, Variable Setpoint (evap-cooled)	new	$/Discharge Grp	$0.00	$0.00	$0.00	Required per T24. Scope limited to retrofit on workpapers
D03-224	FHP, Variable Setpoint (evap-cooled)	retrofit	$/Discharge Grp	$4,709.27	$4,897.46	$9,606.73	
D03-225	FHP, Variable Setpt & Speed (air-cooled)	new	$/Discharge Grp	$0.00	$0.00	$0.00	Required per T24. Scope limited to retrofit on workpapers
D03-225	FHP, Variable Setpt & Speed (air-cooled)	retrofit	$/Discharge Grp	$6,241.47	$8,183.98	$14,425.45	
D03-226	FHP, Variable Setpt & Speed (evap-cooled)	new	$/Discharge Grp	$0.00	$0.00	$0.00	Required per T24. Scope limited to retrofit on workpapers
D03-226	FHP, Variable Setpt & Speed (evap-cooled)	retrofit	$/Discharge Grp	$7,390.00	$8,241.40	$15,631.40	
TBD	Strip Curtains on Walk-Ins, Doors 42" Wide or Less	retrofit	$/SF	$8.97	$3.45	$12.42	
TBD	Strip Curtains on Walk-Ins, Doors greater than 42" Wide	retrofit	$/SF	$10.75	$2.04	$12.78	
TBD	LED lights in reach-in display cases	retrofit	$/mullion	$178.05	$40.24	$218.29	
TBD	LED lights in open display cases	retrofit	$/lamp	$219.17	$30.70	$249.87	

Summary Table – Industrial Measures

Measure ID	Measure Description	Base of Measure	Cost Unit	Equipment Cost (per unit)	Labor Cost (per unit)	Installed Cost (per unit)	Notes
D03-306	Floating suction pressure	new	$/suct grp	$0	$0	$0	All hardware requirements are standard on new systems. Does not qualify under criteria described in utility workpapers
D03-306	Floating suction pressure	retrofit	$/suct grp	$4,865	$7,877	$12,742	
D03-307	FHP, fixed setpoint (evap cooled)	new	$/disch grp	$0	$0	$0	Required per T24. Scope limited to retrofit on workpapers
D03-307	FHP, fixed setpoint (evap cooled)	retrofit	$/disch grp	$2,012	$4,574	$6,586	
D03-308	FHP, variable setpt (evap cooled)	new	$/disch grp	$0	$0	$0	Required per T24. Scope limited to retrofit on workpapers
D03-308	FHP, variable setpt (evap cooled)	retrofit	$/disch grp	$2,713	$4,798	$7,510	
D03-309	FHP, VSP and VFD (evap cooled)	new	$/disch grp	$0	$0	$0	Required per T24. Scope limited to retrofit on workpapers
D03-309	FHP, VSP and VFD (evap cooled)	retrofit	$/disch grp	$5,894	$8,241	$14,135	

The approach for each measure cost analysis gave consideration to the elements which were most important, to avoid details that minimally affected bottom-line measure cost. In some instances, this required more focus on the hardware costs, and in others an understanding of installation labor or other factors was more important. Most measures required engineering of a sample system configuration and hardware selections.

The cost buildups incorporated sections for hardware and parts costs, either as a full cost or incremental comparison, along with a section for labor (design, construction, start-up and fine-tuning), project management, and other factors that would normally be incurred. Equipment and materials costs were obtained by several general methods, depending on the subject hardware:

- Published list prices, with multipliers applied for contractor or end-user. Multipliers were obtained from both OEMs and contractors and compared with past experience.
- RFPs for specific equipment or parts selections, from manufacturers or OEMs.
- Parts price quotes from refrigeration wholesalers.

- Certain measure costs were pursued from California refrigeration contractors, including Source Refrigeration, Hussmann (Ingersoll-Rand) and others.

Labor Costs

The following labor cost assumptions were used in the EEM cost buildups:

Classification	Labor Rate
Commercial Store Employee	$8.00/hr (minimum wage)
Laborer, General Service	$60.00/hr
Fabricator	$60.00/hr
Field Technician	$90.00/hr
Engineer	$95.00/hr
Programmer	$115.00/hr

Measure 1: Automatic Door Closers on Main Walk-In Doors

Measure Description

Install automatic door closer on walk-in cooler and freezer doors. These measures are limited to the retrofit of doors not previously equipped with auto-closers, and assume the doors have strip curtains.

Measure Type: Retrofit

Base Case by Vintage:

- < 1978: No auto-closers
- 1978-1991: No auto-closers
- 1992-2000: No auto-closers
- >2000: No auto-closers
- New-Construction Code Minimums:
    - Federal legislation HR6 - Energy Independence and Security Act (EISA) of 2009 requires all walk-in box doors less than 3’ 9” wide and less than 7’ tall to have automatic door closers that firmly close all walk-in doors that have been closed to within 1 inch of full closure. EISA also requires strip doors, spring hinged doors, or another method of minimizing infiltration when the doors are open
    - California Title 20 codes are same as EISA regulations

Changes to Measure Subdivisions

Previous DEER work did not distinguish between smaller (e.g. “person-sized”) doors and larger cargo doors. Propose subdividing the measure to include a measure for doors less than 42” wide and less than 7’ tall, and a separate measure for larger doors. Note that this measure is for retrofits only—door closers are mandated by federal walk-in standards for new construction.

Measure Notes

For opaque, insulated walk-in box doors less than 42” wide, walk-in box manufacturers have indicated that spring-loaded hinges or gravity-driven cam-style door hinges have been standard for several decades. This is congruent with comments from independent field technicians, who also indicated that they have received utility incentives for installing just the snubber-style door closer which completely closes the door if it is closed to within 1”. Accordingly, this analysis assumed that the measure cost would be for the field-installation of a snubber-style door closer for doors less than 42” wide.

Figure 1: Snubber-type door closer

In general, walk-in box manufacturers indicated that the snubber-style door closers are not compatible with doors larger than 42” wide for a number of reasons, one being that these types of doors typically use latching door handles that do not work with snubbers (with one dissenting manufacturer installing both types of door closers, plus a magnetic door seal). These doors typically get a hydraulic or spring-loaded armature-style door closer. Armature-style closers are effective at closing the door to within 1" of closing but may not completely close and latch the door shut, especially if the door is only partially opened and then let go. One walk-in box manufacturer indicated that there is no straight-forward technology for tight-closing the door once it is closed to within 1" for this size door. They suggested that a more powerful armature door closer can be used, but is not recommended since it makes the door hard to open and unsafe if fingers get caught in the door jamb. This analysis assumed that the measure cost would be for the field-installation of a hydraulic armature-style door closer specifically manufactured for a 60" wide door.

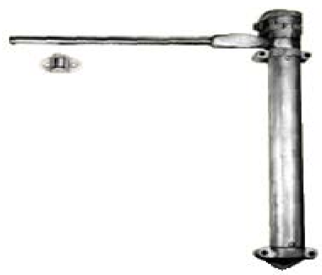


Figure 2: Armature-style door closer

Measure Description and DEER Database ID	Cost Analysis Subdivisions	Costing Basis	Costing Method
Auto-closers on main walk-in doors	Opaque, insulated swing door (<42" wide), retrofit	Field-installation of one snubber-style door closer, 36"W x 84"H freezer door,	Build up costs consisting of hardware, installation, and contractor mark-ups. Validate with contractor cost estimates
D03-208 (coolers), D03-209 (freezers)	Opaque, insulated swing door (42-72" wide), retrofit	60"W x 84"H freezer door, one armature-style spring-loaded door closer specifically manufactured for this size door	Build up costs consisting of hardware, installation, and contractor mark-ups. Validate with contractor cost estimates

Measure Cost Buildup

- Doors under 42" wide

Item	Description	Source	Units	Qty	Cost ea.	Contractor Margin	Price
	Equipment						
1	Snubber Door Closer	RHS Corporation	closer	1	$ 103.11	0.34	$156
2	**Materials**						
3	None assumed						$0
4	**Labor and Subcontracts**						
5	Labor to install autocloser	Estimate	person-hrs	1	$60		$60
6	**Others**						
7	Taxes and Permits		%		0%		$0
8	Contingency Costs		%		5%		$10.78
		Total					$226
		Total Capacity or Size			Per cooler door		1
		Costing Units			$/cooler door		$226

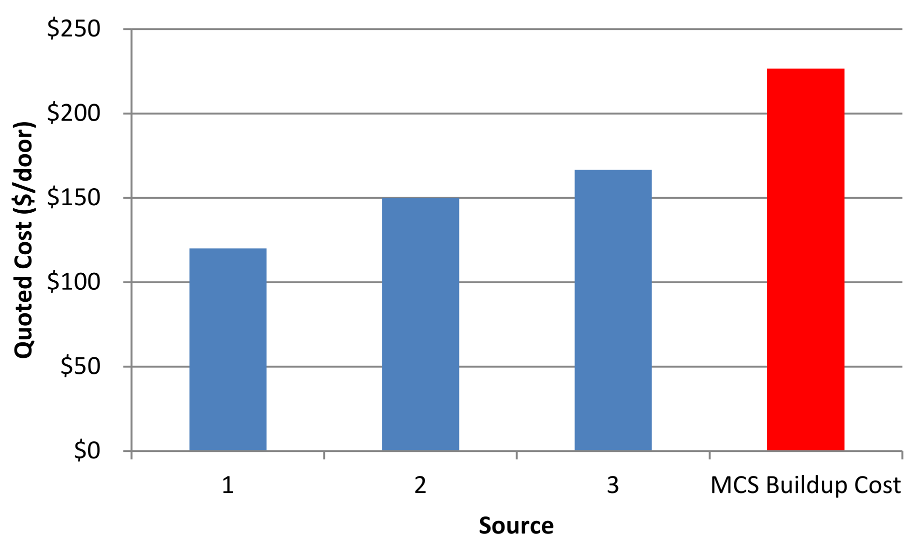
- Doors over 42" wide

Item	Description	Source	Units	Qty	Cost ea.	Contractor Margin	Price
	Equipment						
1	Armature Door Closer	RHS Corp.	closer	1	$ 607.54	0.34	$917
2	**Materials**						
3	None assumed						$0
4	**Labor and Subcontracts**						
5	Labor to install autocloser	Estimate	person-hrs	1.5	$60		$90
6	**Others**						
7	Taxes and Permits		%		0%		$0
8	Contingency Costs		%		5%		$50
				Total			$1,058
				Total Capacity or Size	Per cooler door		1
				Costing Units	$/cooler door		$1,058

Benchmark Validation

- Doors under 42" wide

Vendor Quote	Source	Price/Door	Notes
1	Energy Saving Solutions	$120	Quoted price for installation and hardware. Probably represents the low-end of the market (the quoted installed cost for the snubber is less than the wholesale hardware cost quoted by other sources)
2	La Costa Doors	$150	Quoted $75 per door for hardware to the companies doing the upgrade. Assumed 0.25 contractor markup. La Costa estimated installation labor running at $50 per door
3	Bally Refrigeration Boxes	$167	Quoted $125 cost for the snubber to a foodservice dealer. Assumed markup of 0.25 by foodservice dealer. **Cost does not include installation labor** (this represents the option cost from the box OEM, and does not include costs associated with field-retrofitting the hardware)
MCS Buildup Cost		**$226**	



- Doors over 42” wide

Vendor Quote	Source	Price/Door	Notes
3	Bally Refrigeration Boxes	$645	Quoted $400 cost for the hydraulic armature-style door closer to a foodservice dealer. Assumed markup of 0.25 by foodservice dealer. **Cost does not include installation labor** (this represents the option cost from the box OEM, and does not include costs associated with field-retrofitting the hardware)
MCS Buildup Cost		**$1,058**	

Measure 2: Strip Curtains on Doorways to Refrigerated Spaces

Measure Description

Install strip curtains or plastic swinging doors on doorways of refrigerated walk-in boxes and refrigerated storage spaces.

Measure Type: Retrofit, Replace-On-Burnout

Base Case by Vintage:

- < 1978: No strip curtains (Retrofit), damaged curtains (Replace-On-Burnout)
- 1978-1991: No strip curtains (Retrofit), damaged curtains (Replace-On-Burnout)
- 1992-2000: No strip curtains (Retrofit), damaged curtains (Replace-On-Burnout)
- >2000: No strip curtains (Retrofit), damaged curtains (Replace-On-Burnout)
- New-Construction Code Minimums:
    - Federal legislation HR6 - Energy Independence and Security Act (EISA) of 2009 requires strip doors, spring hinged doors, or another method of minimizing infiltration when the doors are open
    - California Title 20 codes are same as EISA regulations
    - California 2014 Title 24 for refrigerated warehouses requires passageways between refrigerated spaces that are maintained at different temperatures to have infiltration barriers, which may be strip curtains, but may also be automatic-closing rollup or bi-parting doors or air curtains.

Changes to Measure Subdivisions

Not applicable; strip curtains are not currently in the DEER database.

Measure Notes

There are many different types of strip curtain materials available, and each is suited to a particular door size, application temperature, and type and frequency of door traffic. Product quality (and price) is also widely variable. According to strip curtain installers interviewed for this analysis, the lower-quality strip curtains usually last about one year under typical traffic conditions. Higher-quality strips may last 5 years or more. Some installers indicated that if the strip curtains are less than five years old and one strip is damaged, then the individual strip may be replaced. However, most installers indicated that standard practice is to replace the entire strip curtain, even if only a few strips are damaged. Manufacturers indicated that the cost is lower if the strip curtains are purchased as part of a kit that is manufactured for a standard door size, and cost goes up if the manufacturer regards the door size as “custom”.

Measure Description and DEER Database ID	Cost Analysis Subdivisions	Costing Basis	Costing Method
Strip curtains on main walk-in doors (Currently no DEER database ID)	Walk-in, man-door, retrofit and replace-on-burnout	36"W x 84"H cooler door, foot traffic only	Build up costs consisting of hardware, installation, and contractor mark-ups. Verify with contractor estimates.
	Warehouse door, oversize, retrofit and replace-on-burnout	72"W x 84"H cooler door, forklift and pallet-jack traffic	Build up costs consisting of hardware, installation, and contractor mark-ups. Verify with contractor estimates.

Measure Cost Buildup

- Person-door (less than 36" wide)

Item	Description	Source	Units	Qty	Cost ea.	Contractor Margin	Price
	Equipment						
1	New strip curtain material and mounting hardware	Aggregated source	Sq. Ft.	21	$6	0.34	$203
2	**Materials**						
3	None assumed						$0
4	**Labor and Subcontracts**						
5	Install strip curtains	Estimate	Person-Hrs	1	$60		$60
6	**Others**						
7	Taxes and Permits		%		0%		$0
8	Contingency Costs		%		5%		$13
				Total			$276
				Total Capacity or Size	Per Square Foot		21.0
				Costing Units	$/SF		$13.1

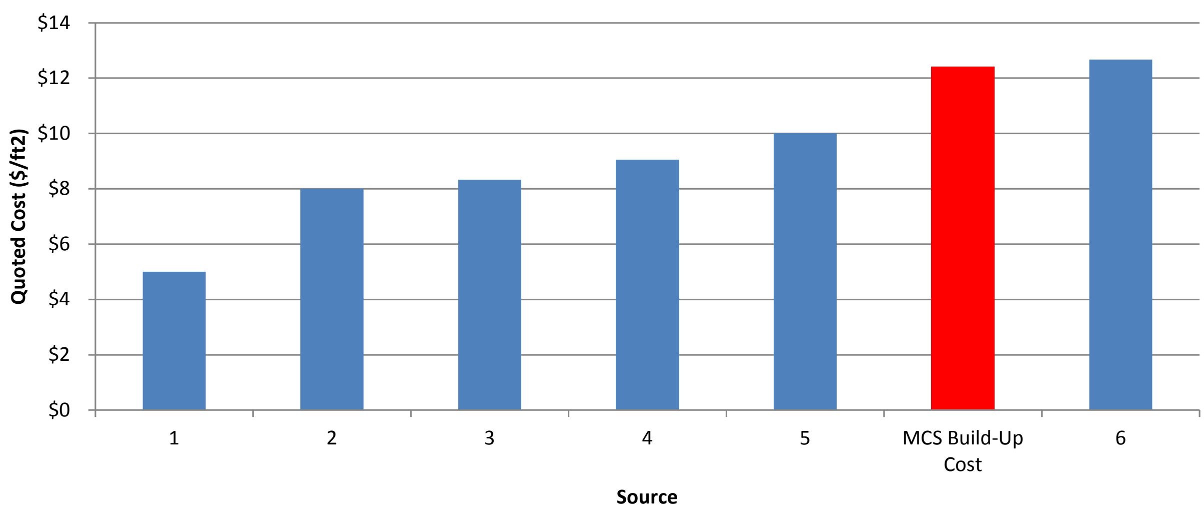
- Cargo door (greater than 36" wide)

Item	Description	Source	Units	Qty	Cost ea.	Contractor Margin	Price
	Equipment						
1	New strip curtain material and mounting hardware	Aggregated source	Sq. Ft.	42	$7	0.34	$451
2	**Materials**						
3	None assumed						$0
4	**Labor and Subcontracts**						
5	Install strip curtains	Estimate	hrs	1	$60		$60
6	**Others**						
7	Taxes and Permits		%		0%		$0
8	Contingency Costs		%		5%		$26
				Total			$537
				Total Capacity or Size	Per Square Foot		42.0
				Costing Units	$/SF		$12.8

Benchmark Validation

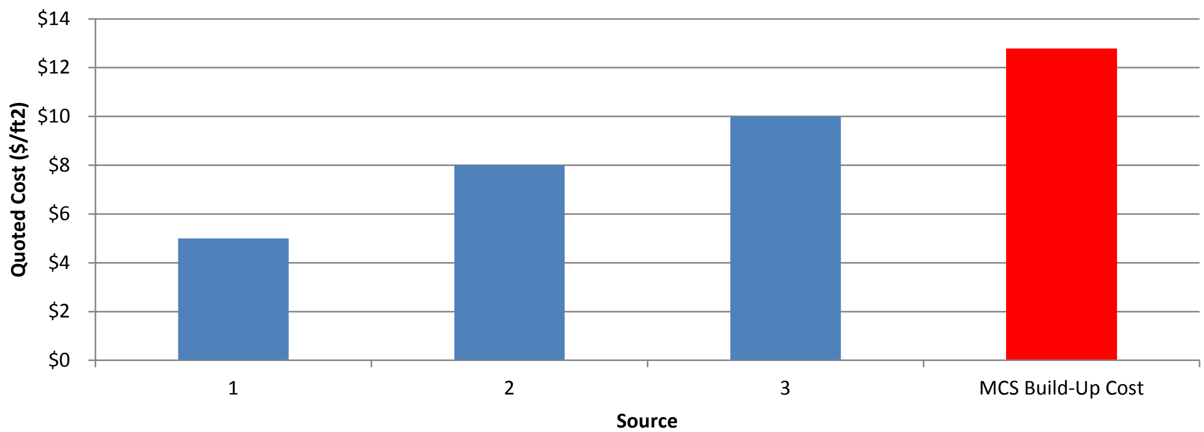
- Person-door (less than 36” wide)

Vendor Quote	Source	Price/SF	Notes
1	Energy Saving Solutions	$5.00	Charges $3 if the door qualifies for an incentive.
2	Energy Wise America	$8.00	Low-end quoted price from this source
3	Trafficdoorsandmore.com	$8.33	Typical cost for coolers, based on 21 square-foot man-door
4	Trafficdoorsandmore.com	$9.05	Typical cost for freezers, based on 21 square-foot man-door
5	Energy Wise America	$10.00	High-end quoted price from this source
Measure Cost Buildup		$12.42	Does not include contractor markup of strip material. Installers appear to make their money on labor, not on material.
6	Arctic Repair, Inc.	$12.67	Material cost is $1.15/ft for 8" wide freezer material. Assume 50% overlap on strips and 3" on either side. Hanger material is $8/ft. Estimate 1 hour to cut the strips and punch the holes, etc., and 1 hour to install the curtain, plus travel time. Labor rate is $77/hr. Calculated cost using these numbers is $12.70 per square foot.



- Cargo door (greater than 36” wide)

Vendor Quote	Source	Price/SF	Notes
1	Energy Savings Solutions	$5.00	$3 if qualifying for incentive
2	Energy Wise America	$8.00	Low-end quoted price from this source
3	Energy Wise America	$10.00	High-end quoted price from this source
Measure Cost Buildup		$11.99	



Measure 3: Retrofit Glass Doors on Open Medium-Temperature Refrigerated Display Cases

Measure Description

Add glass reach-in merchandizing doors to medium temperature open vertical refrigerated display cases

Measure Type: Retrofit

Base Case by Vintage:

- < 1978: No doors on open multi-deck cases
- 1978-1991: No doors on open multi-deck cases
- 1992-2000: No doors on open multi-deck cases
- >2000: No doors on open multi-deck cases
- New-Construction notes:
  - Measure does not apply for new construction projects—door cases would be ordered instead

Changes to Measure Subdivisions:

None assumed

Measure Notes

Installers who perform this measure indicated that there is a large variation in price based on a number of factors. One installer, who has completed over 90 projects nationwide, noted that they would like to develop a per-door or per-foot price model for marketing this measure, but to-date they are unable to do so because of the number of variables. Technical considerations include:

- Whether the existing case has adjustable thermal expansion valve (TXVs) or if the TXV has to be replaced. One installer indicated that every project requires a TXV change.
- Whether the store air conditioning system can handle the additional latent load that was previously handled by the display case.
- Whether the suction group serving the display case lineup has adequate capability to vary its capacity, since the suction group capacity is mismatched to the display case load after the retrofit. If not, compressors must be removed (with suction and discharge header modifications) or replaced.
- Whether suction groups need to be re-headered to allow for higher rack saturated suction temperatures (SST).
- Whether the store uses distributed compressor racks, which present a unique challenge since smaller case loads cannot be combined to make use of existing line sets like they can be on stores with central compressor rooms.
- Whether the display cases themselves require modification beyond just the addition of doors. One installer included removing select fans from display cases for additional energy savings.

Customers must also choose from several different cost-adding options, such as LED mullion lights versus T5 (although installers indicated that nearly all installations are now LED), and anti-sweat heater control options. Depending on the application, customers sometimes choose to use shelf lighting instead of mullion lighting, which can either reduce cost if shelf lights were installed previously or increase cost if they must be installed.

One installer indicated that the retrofit is sometimes not possible due to the proximity of the display case to dry product shelves or other adjacent door cases, since there must be adequate space in the aisle to accommodate shopping cart traffic when the display doors are open.

Most installers indicated that the cost for this measure is generally the same for larger national chains as it is for independent stores, although one installer had a reduced price for a large national account.

Measure Description and DEER Database ID	Cost Analysis Subdivisions	Costing Basis	Costing Method
Retrofit glass doors on open MT cases, additional lighting D03-206	High-efficiency door, includes mullion anti-sweat heaters only (example: Anthony Eliminaator II, Anthony Vista C, Hussmann Innovator II and Innovator III)	Retrofit 124' of open MT deli case with reach-in doors, mullions, and LED mullion lights. Adjust thermostatic expansion valves, replace suction line risers, electrical re-circuiting for LED lights and anti-sweat heaters, enclose both lineup ends, re-commission energy management system (EMS). Assume dry product shelves do not need to be relocated to accommodate new reach-in case doors.	Build up costs consisting of hardware, installation, refrigeration fine-tuning, disposal, and contractor mark-ups. Verify with contractor estimates and quotes for turn-key retrofit programs

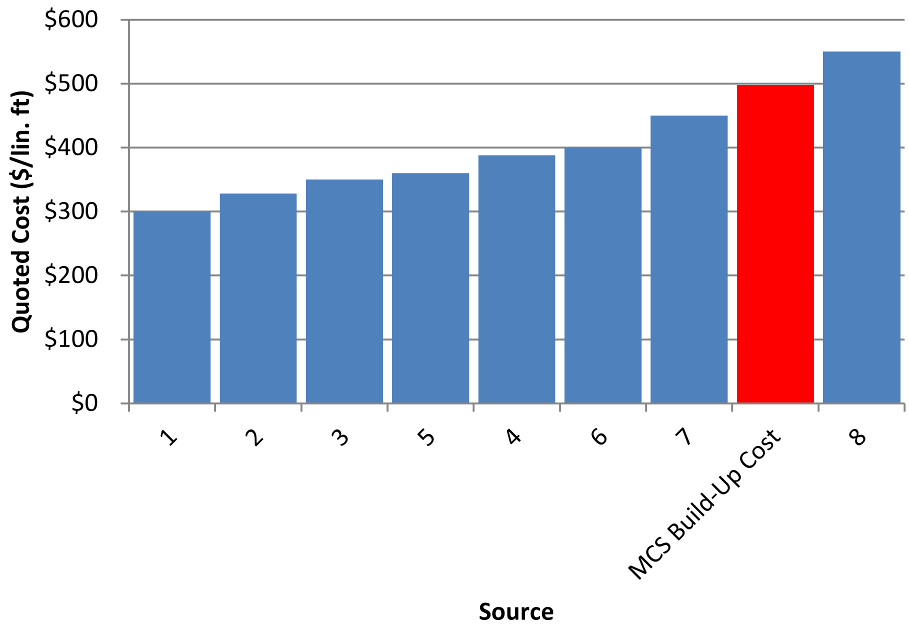
Measure Cost Build-Up

Item	Description	Source	Units	Qty	Cost ea.	Contractor Margin	Price
	Equipment						
1	Retrofit MT doors	Hussmann	Ft.	124	$285	included	
2	Retrofit MT doors	Styleline	Ft.	124	$322	included	
3	Retrofit MT doors	Source Refrigeration	Ft.	124	$385	included	
4		Average	Ft.	124	$303		$37,584
5	**Materials**						
6	End Caps	Anthony Int'l		2	$600	included	$1,200
7	Electrical Materials to connect lights, anti-sweat heaters	Estimate		1	$500		$500
8	Refrigeration piping and materials	Estimate		1	$500		$500
9	**Labor and Subcontracts**						
10	Survey and Engineering	Estimate	person-hrs	28	$95		$2,660
11	Labor to set doors	Anthony Int'l	person-hrs	78	$90		$7,020
12	Electrical re-circuiting	Anthony Int'l	person-hrs	10	$90		$900
13	Adjust expansion valves and EPRs	Estimate	person-hrs	16	$90		$1,440
14	Change suction risers	Estimate	person-hrs	20	$90		$1,800
15	Suction group changes	Estimate	person-hrs	20	$90		$1,800
16	EMS changes and system tuning	Estimate	person-hrs	8	$115		$920
17	**Others**						
18	Taxes and Permits	Estimate	%		0%		$0.00
19	Contingency Costs	Estimate	%		5%		$2,816.19
20	Dumpster Fees	Anthony Int'l	Days	4	$71		$286
21	Freight	Hussmann			$3,500		
22		Anthony Int'l			$1,107		
23		Average			$2,304		$2,304
		Total					$61,729
		Total Capacity or Size			Lin. Ft. of MT case		124
		Costing Units			$/Lin. Ft. of MT case		$497.82

Benchmark Validation

Vendor Quote	Source	Price/Lin ft. Door	Notes
1	Anthony International	$300	Turn-key program (e.g. "Close the Case") for a typical customer (e.g. not Walmart), bottom-of-the-line Anthony 101 doors. Cost includes the doors, frames, mullions, new facing, LED lights, door installation labor, electrical re-circuiting, and adjusting expansion valves and EPRs. The cost does not capture engineering costs, suction group adjustments (e.g. installing unloaders, removing or replacing compressors), changing suction risers. These doors are deeply discounted off list price. Anthony reports that these adjustments are contracted to outside refrigeration contractors.
2	Anthony International	$328	Turn-key program (e.g. "Close the Case"), Anthony Vista C doors, exclusive price offered only to Walmart. Cost includes the doors, frames, mullions, new facing, LED lights, door installation labor, electrical re-circuiting, and adjusting expansion valves and EPRs. The cost probably does not include engineering costs, suction group adjustments (e.g. installing unloaders, removing or replacing compressors), changing suction risers, or HVAC system modifications. Anthony reports that these adjustments are contracted to outside refrigeration contractors. Hardware costs are deeply discounted—the so called "turnkey" cost per foot for a whole project is cheaper than the purchase price offered to a more typical customer for just the door hardware.
3	Enreps LLC	$350	Enreps estimate for the low-end installed cost for doors, frames, LED lights. This is using Remis doors, which do not have Anti-sweat heat in them and therefore do not require electrical recircuiting. **This price is for installing doors and related hardware only and does not include ANY refrigeration system adjustments.**
4	Anthony International	$360	Turn-key program (e.g. "Close the Case") for a typical customer (e.g. not Walmart), using Anthony Vista B doors. Cost includes the doors, frames, mullions, new facing, LED lights, door installation labor, electrical re-circuiting, and adjusting expansion valves and EPRs. The cost probably does not include engineering costs, suction group adjustments (e.g. installing unloaders, removing or replacing compressors), changing suction risers, or HVAC system modifications. Anthony reports that these adjustments are contracted to outside refrigeration contractors.
5	Hussmann	$388	Built-up cost, EcoVision doors, includes door hardware with LED lights, installation costs, and adjusting or changing out the TXVs. The cost ignores much of the refrigeration system adjustment costs, such as changing suction risers, compressor sequencing changes and/or swapping out compressors, suction line recircuiting (which could be a lot with Hussmann's distributed "Protocol" refrigeration systems.
6	Enreps LLC	$400	Enreps estimate for the high-end installed cost for doors, frames, LED lights. This is using Remis doors, which do not have Anti-sweat heat in them and therefore do not require electrical recircuiting. **This price is for installing doors and related hardware only and does not include ANY refrigeration system adjustments.**
7	Anthony International	$450	Turn-key program (e.g. "Close the Case") for a typical customer (e.g. not Walmart), top-line Vista B doors. Cost includes the doors, frames, mullions, new facing, LED lights, door installation labor, electrical re-

			circuiting, and adjusting expansion valves and EPRs. The cost probably does not include engineering costs, suction group adjustments (e.g. installing unloaders, removing or replacing compressors), changing suction risers. These doors are deeply discounted off list price.
Measure Cost Buildup		**$497.82**	
8	Source Refrigeration	$550	Built-up price for stores in metro areas. Includes survey, engineering, door cost, installation, EMS Commissioning and startup, freight, disposal, and travel. **This probably represents the most comprehensive cost build-up provided by any vendor**.



Measure 4: Replace Open Medium-Temperature Display Cases with New Cases with Reach-In Doors

Measure Description

Replace existing open medium-temperature fixtures with new fixtures having glass doors. The new fixtures are assumed to have standard doors, ECM motors, and LED lighting.

Measure Type: Retrofit

Base Case by Vintage:

- < 1978: Open MT cases
- 1978-1991: Open MT cases
- 1992-2000: Open MT cases
- >2000: Open MT cases
- New-Construction Code Minimums:
    - Not applicable. Glass door cases would be specified for new-construction projects

Changes to Measure Subdivisions

None

Measure Notes

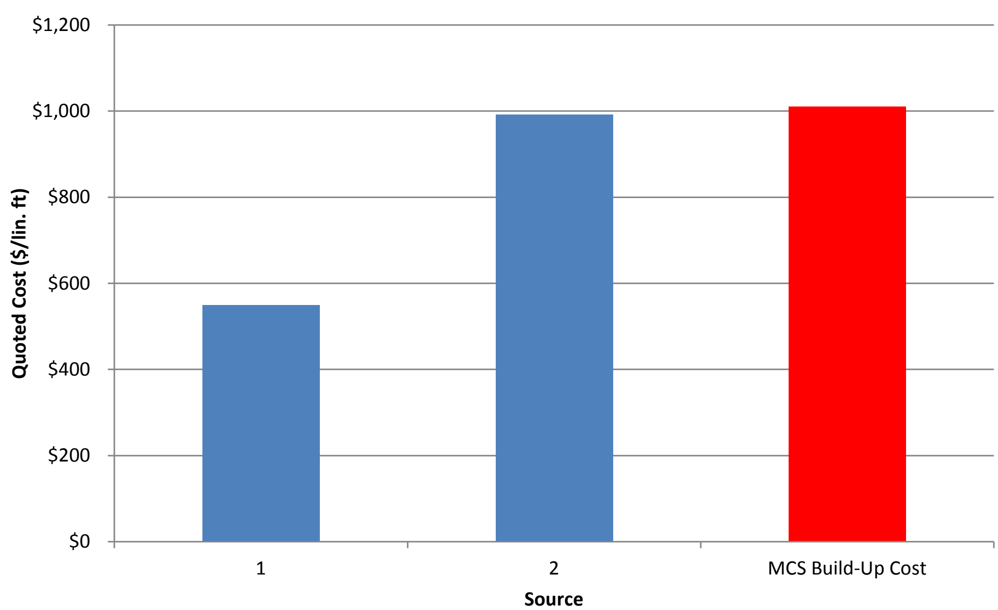
Installers for this measure cited many of the same challenges as the medium-temperature door retrofit measure for why it is difficult to quote a per-foot costing basis. Like the door retrofit measure, the installer must consider suction riser changes, suction group changes (either removing or replacing compressors), and air conditioning changes if the existing AC system cannot handle the additional cooling requirement and latent load associated with changing from open case lineups to door cases. Proximity to unrefrigerated product shelves was also cited as a potentially large cost adder if the shelves must be moved (one installer indicated that they had passed on several projects for this reason). One installer indicated that the floor drains may need to be moved to accommodate a new display case design, which would require jackhammering the floor, although another installer stated that this wasn't typically an issue.

Measure Description and DEER Database ID	Cost Analysis Subdivisions	Costing Basis	Costing Method
Replace open MT cases with new case with doors D03-207	High-efficiency door, includes mullion anti-sweat heaters only (example: Anthony Eliminaator II, Anthony Vista C)	Replace 124' of open MT deli case with reach-in door cases. Replace suction line risers, electrical re-circuiting for LED lights and anti-sweat heaters, re-commission energy management system (EMS). Assume product shelves do not need to be relocated to accommodate new reach-in case doors. Assume floor drains do not need to be relocated.	Build up costs consisting of hardware, installation, refrigeration fine-tuning, disposal, and contractor mark-ups. Verify with contractor estimates.

Measure Cost Buildup

Item	Description	Source	Units	Qty	Cost ea.	Contractor Margin	Price
	Equipment						
1	New MT Glass Door Case	Hussmann	Ft.	124	$774	Included	
2	New MT Glass Door Case	Source Refrigeration	Ft.	124	$550	Included	
3		Average	Ft.	124	$662		$82,100
4	**Materials**						
5	Piping materials	Estimate		1	$1,800		$1,800
6	Electrical materials to reconnect fans, lights, anti-sweat heaters	Estimate		1	$1,200		$1,200
7	**Labor and Subcontracts**						
8	Survey and Engineering	Estimate	person-hrs	28	$95		$2,660
9	Pump down system	Estimate	person-hrs	8	$90		$720
10	Remove old cases, reset new ones	Estimate	person-hrs	144	$90		$12,960
11	Electrical re-circuiting	Estimate	person-hrs	48	$90		$4,320
12	Change suction risers	Estimate	person-hrs	20	$90		$1,800
13	Charge and restart system	Estimate	person-hrs	8	$90		$720
14	Compressor sequencing changes	Estimate	person-hrs	20	$115		$2,300
15	EMS changes and system tuning	Estimate	person-hrs	8	$115		$920
16	**Others**						
17	Taxes and Permits		%		0%		$0
18	Contingency Costs		%		5%		$5,575
19	Forklift, trucking (local) and disposal	Estimate		1	$2,000	0.38	$2,760
20	Freight	Hussmann		1	$5,500	0.00	$5,500
21							$0
22							$0
				Total			$125,335
				Total Capacity or Size	Lin. Ft. of MT case		124
				Costing Units	$/Lin. Ft. of MT case		$1,010.77

Benchmark Validation



Measure 5: Evaporator Fan Controls

Measure Description

The evaporator fans served by single-compressor condensing units typically run continuously (except during defrost for some applications where reverse-cycle hot gas defrost is employed), even when the compressor is not on and no refrigeration is occurring. This measure includes control additions and motor changes to either duty cycle the evaporator fans or reduce the speed of evaporator fans when the compressor is off. This measure applies only to evaporator coil fans served by single-compressor suction groups.

Measure Type: Retrofit

Base Case by Vintage:

- < 1978: Fans run continuously; shaded pole motors
- 1978-1991: Fans run continuously; shaded pole motors
- 1992-2000: Fans run continuously; shaded pole motors
- 2000-2005: Fans run continuously; shaded pole motors
- 2005: Fans run continuously; Electronically-commutated (EC) motors
- New-Construction Code Minimums:
    - Federal legislation HR6 - Energy Independence and Security Act (EISA) of 2009 requires all walk-in evaporator fan motors less than 1 HP to be either EC or AC induction motors
    - California Title 20 codes are same as EISA regulations
    - 2014 California Title 24 codes requires all refrigerated warehouse evaporator coil fans served by single-compressor suction groups without compressor unloaders to either reduce speed or duty cycle when the compressor is off. This requirement applies to evaporators serving refrigerated spaces that are greater than 3,000 square feet of floor area.

Changes to Measure Subdivisions

For fan motors less than 1 HP and less than 460V, walk-in box manufacturers are offering fan duty-cycling or two-speed fan operation during the compressor off-cycle either as their standard offering or as a no-cost adder. Therefore, a 'new construction' vintage measure cost was not included in this analysis for walk-in unit coolers less than 1 HP and less than 460V.

The DEER measure is for walk-in box retrofit applications with the measure including swapping PSC fan motors for ECM as well as control additions. The fan motors are typically <1 HP. We propose expanding the measure into two measures, one for retrofit projects involving swapping PSC motors less than 1 HP for ECM as described in the current DEER measure, and another measure for both retrofit and new-construction projects involving 3-phase, 460V motors greater than 1 HP. The additional measure would not include the single-compressor suction group requirement. In addition, the DEER measure description limits this measure to duty-cycling fans, while reducing fan speed would yield the same (or more) energy savings and may be more common and easier.

Measure Notes

This measure cost buildup includes a "fan controller" product, since industry research showed that this is the predominantly-used method, although duty-cycling the fans can be accomplished without one. A wire could be run off the compressor contactor through a timer to the fan contactors. Hardware cost would be nominal and overall measure cost would be primarily driven by labor to perform the upgrade.

Measure Description and DEER Database ID	Cost Analysis Subdivisions	Costing Basis	Costing Method
Duty cycle, stage off, or reduce speed of evaporator fans when condensing unit compressor cycles off D03-210	Retrofit controls for unit cooler with <1 HP permanent split capacitor (PSC) motors, (retrofit includes motor swap to electronically-commutated motors)	Walk-in cooler with two 2-fan unit coolers, 1/15 HP motors	Build up costs consisting of hardware, installation, and contractor mark-ups. Verify with contractor estimates.
To Be Determined	Retrofit controls for air unit with >1 HP 3-phase 460V motors. Measure includes variable-speed drives for each unit cooler	Point of Sale (POS) freezer in a big-box retail store, 4x unit coolers, 2x 2HP fans per unit cooler.	Build up costs consisting of hardware, installation, and contractor mark-ups.
	New controls for air unit with >1 HP 3-phase 460V motors. Measure includes variable-speed drives for each unit cooler	Point of Sale (POS) freezer in a big-box retail store, 4x unit coolers, 2x 2HP fans per unit cooler.	Build up costs consisting of hardware, installation, and contractor mark-ups.

Measure Cost Build-Up

- Small unit coolers <1 HP, duty cycle or low speed when compressors are off

Item	Description	Source	Units	Qty	Cost ea.	Contractor Margin	Price
	Equipment						
1	Fan Controller	Sierra Business Council	Controller	1	$317		
2	Fan Controller	Frigitek	Controller	1	$335		
3	Fan Controller	Supermarket Energy Technologies	Controller	1	$300		
4	Average		Controller	1	$317	0.34	$479
5	Fan Motor, 1/15 HP, ECM	Sierra Business Council	Motor	4	$170		
6	Brushless DC Motor, ECM,1/15 HP, 1550 rpm, 115 V	Grainger	Motor	4	$142		
7	Brushless DC Motor, ECM,1/15 HP, 1550 rpm, 208-230 V	Grainger	Motor	4	$141		
8	1/15 or 1/20 HP, 2-speed	Frigitek	Motor	4	$147		
9	Average		Motor	4	$150	0.34	$905
10	**Materials**						
11	Incidental electrical installation materials	Estimate		1	$300		$300
12	**Labor and Subcontracts**						
13	Installation Labor	Estimate	Person-hrs	5	$90		$450
14	Labor to program, test, and adjust	Estimate	Person-hrs	2	$115		$230
15	Taxes and Permits		%		0%		$0
16	Contingency Costs		%		5%		$118.19
				Total			$2,482
				Total Capacity or Size	Per motor		4
				Costing Units	$/motor		$620

- Large unit coolers >1 HP, variable-speed control

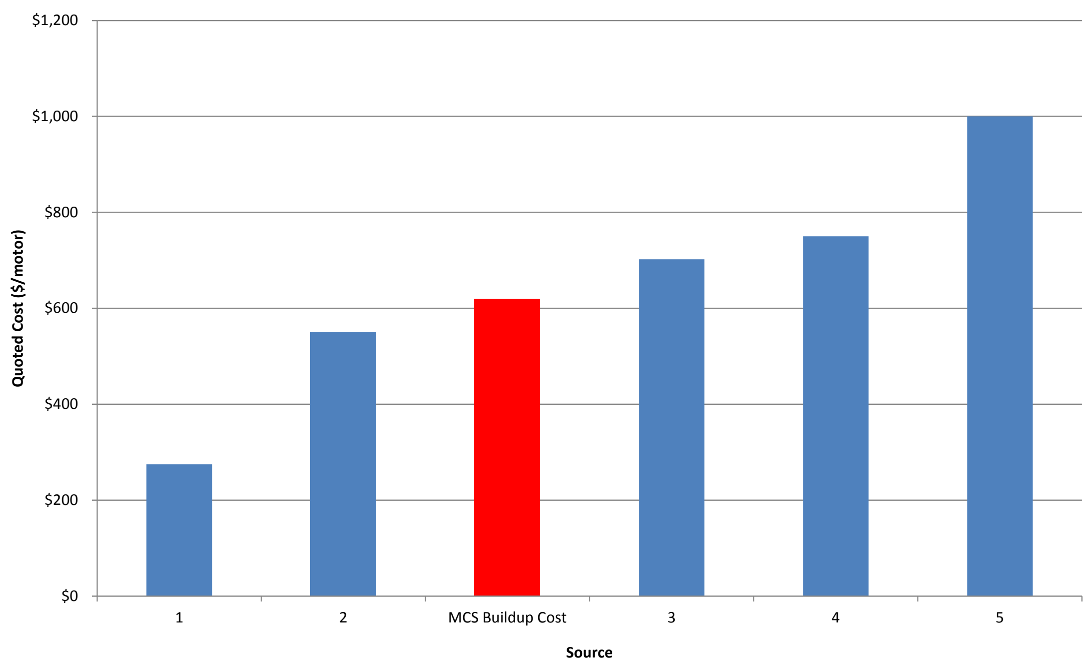
Item	Description	Source	Units	Qty	Cost ea.	Contractor Margin	Price
	Equipment						
1	VFD-ready drop-in replacement motor	R.E. Michael	per motor	8	$354	0.34	$4,279
2	ABB VFD, 5 HP	Western Switches & Controls	per VFD	4	$527	0.34	$3,179
3	**Materials**						
4	Enclosure 3' x 5'	SCE	Per Enclosure	1	$600	0.34	$906
5	Backplate	Estimate	Per Backplate	1	$50	0.34	$75
6	Circuit breaker, 277V, 20Amp, 1 Pole, DIN-rail mount	Mag-Trol, Inc.	Per CB	4	$16	0.34	$94
7	Fuse Holder, GSC Fuse, UL	Mag-Trol, Inc.	Per Fuse	4	$4	0.34	$24
8	Fuse, 5A, Miniature Glass, Time Delay, UL	Mag-Trol, Inc.	Per Fuse Holder	4	$1	0.34	$5
9	Ground Bar	Mag-Trol, Inc.	Per Bar	1	$8	0.34	$12
10	Labels	Hawk Signs	Per Panel	1	$30	0.34	$45
11	Wiring, Panduit, Fasteners, Connectors, Etc.	Estimate	Per Panel	1	$200	0.34	$302
12	Installation Materials	Estimate	Per Job	1	$250		$250
13	Additional EMS IO	Opto22	Per Job	1	$348	0.34	$525
14							$0
15	**Labor and Subcontracts**						
16	Panel Fabrication	Estimate	hr	20	$60		$1,200
17	Engineering, Drawings, Project Management	Estimate	hr	15	$95		$1,425
18	Panel Installation	Estimate	hr	20	$90		$1,800
19	EMS Programming, fine-tuning	Estimate	hr	8	$115		$920
20							$0
21	Taxes and Permits		%		0%		$0
22	Contingency Costs		%		5%		$752.10
23							
24							
					Total		$15,794
					Total Capacity or Size	Per motor	8
					Costing Units	$/motor	$1,974.26

Benchmark Validation

- Small unit coolers <1 HP, duty cycle when compressors are off

Vendor Quote	Source	Price/Motor	Notes
1	Supermarket Energy Technologies	$275	Estimate includes $300 for a controller and $200 per motor, using the company's proprietary "Fan Ally" controller. Costs are installed costs.
2	Energy Wise America	$550	Estimate $1,100 per 2-motor evaporator for a typical restaurant. Cost includes replacing motors with two-speed EC motors and installing controller. Cost could be more if coils are iced up or dirty, product needs to be moved, voltage is 460V or more. Price is based on 1/15 HP motors typical of walk-in evaporators.
MCS Build-Up Cost		**$620**	**Could be as low as $370 if EC motors are already installed**
3	Energy Industries	$702	This is from an actual quote from an 84-fan industrial warehouse job that included swapping out the motors. Project cost was $59,000. The contractor's off-the-cuff estimate was $800-$1,000 per motor for this measure, so this actual quote is a good reflection of the economy of scale associated with this measure.
4	KE2 Thermsolutions	$750	Estimated installed price from a KE2 Thermsolutions sales engineer. His company's controller duty-cycles the fan rather than dropping to low speed, so replacing motors with ECM is not necessary. This is a high-end controller that also controls the defrost cycle and the compressor with highly-developed proprietary algorithms; it doesn't just duty-cycle the evaporator fans when the compressor is off. Requires installation of three additional temperature sensors per evaporator coil. Since the fans don't have to be swapped out it is difficult to pin down a per-fan cost. One controller is required per

			system (for a walk-in application that usually means one evaporator coil but could be two or more). The per-motor price listed here is based on a restaurant application with two 2-fan evaporator coils on two separate systems. Per-motor cost could be lower or higher depending on the number of fans per coil. Industrial applications would be more depending on where the controller is mounted and how many wire/conduit runs are necessary.
5	Energy Industries	$1,000	Quote from a 5-fan, 2-evaporator job using Frigitek controllers. Total project cost was $5,000. This quote is a good reflection of how hidden costs can affect price. Motor mounts were non-standard, coils were iced up at the start of the project, lots of product had to be moved to get to the coils.



Measure 6: Floating Suction Pressure

Measure Description

Add controls and hardware to multiplex and industrial refrigeration systems to reset the target suction pressure, rather than operating at a fixed suction pressure setpoint. This measure applies to both low-temperature and medium-temperature suction groups.

Measure Type: Retrofit

Base Case by Vintage:

- < 1978: Fixed suction pressure setpoint
- 1978-1991: Fixed suction pressure setpoint
- 1992-2000: Fixed suction pressure setpoint
- 2000-2005: Fixed suction pressure setpoint
- 2005: Fixed suction pressure setpoint
- New-Construction Code Minimums:
    - 2014 California Title 24 codes requires suction groups in commercial refrigeration systems to have floating suction pressure control to reset the saturated suction pressure control setpoint based on the temperature requirements of the attached refrigeration display cases or walk-ins.

Changes to Measure Subdivisions

DEER measure subdivision is design load of subject suction group, in tons. We recommend changing the measure subdivision to number of suction groups. The measure cost is mostly invariable relative to design load, since the hardware requirements are mostly the same for nearly all sizes of systems.

For the industrial new-construction measure, programmable logic controllers (PLCs) and programmable automation controllers (PACs) are now industry-standard on refrigeration control systems, and floating suction pressure logic is widely understood by controls vendors. Temperature sensors in the refrigerated spaces that are connected to the PLC or PAC are also industry-standard on new-construction projects. Therefore the new-construction industrial measure is considered obsolete.

Measure Notes

Microprocessor-based compressor controls with embedded floating suction pressure logic have been ubiquitous on nearly all supermarket parallel rack systems installed in at least the past twenty five years, and we know of no examples of systems in use today without them. The logic to float the suction pressure, however, is not always in use or properly commissioned. The commercial system cost buildup for this measure includes the labor to re-commission the floating suction pressure logic on the existing microprocessor controller.

For the industrial system cost buildup, the cost to procure and install a PLC (programmable logic controller) or PAC (programmable automation controller) and associated I/O is included in the measure cost buildup. Industrial systems, even relatively modern ones, often have no supervisory compressor sequencing or control and instead use local pressure switches or compressor micropanels. In that instance, a supervisory controller would be required for floating suction pressure.

<table>
<tr><th>Measure Description and DEER Database ID</th><th>Cost Analysis Subdivisions</th><th>Costing Basis</th><th>Costing Method</th></tr>
<tr><td rowspan="2">Floating suction pressure control on LT and MT suction groups

D03-220 (Commercial Systems)
D03-306 (Industrial Systems)</td><td>Commercial Multiplex System, Retrofit</td><td>Multiplex supermarket system, legacy electronic controls (electronic compressor sequencer), evaporator pressure regulators on all circuits.</td><td>Build up costs consisting of materials, installation, contractor mark-ups.</td></tr>
<tr><td>Industrial Plant, Retrofit</td><td>Ammonia industrial system, pressure switch compressor control (no centralized control), thermostat control of liquid solenoids</td><td>Build up costs consisting of hardware (new automation controller and IO, installation, and contractor mark-ups.</td></tr>
</table>

Measure Cost Build-Up

- Supermarket multiplex system

Item	Description	Source	Units	Qty	Cost ea.	Contractor Margin	Price
	Equipment						
1	None Assumed						
2	**Materials**						
3	None Assumed						
4	**Labor and Subcontracts**						
5							
6	Engineering, Project Management	Estimate	Person-hrs	16	$95		$1,520
7	Calibration and fine-tuning labor	Estimate	Person-hrs	32	$115		$3,680
8	**Others**						
9	Taxes and Permits		%		0%		$0
10	Contingency Costs		%		5%		$260
				Total			$5,460
				Total Capacity or Size	Per Suction Group		1.0
				Costing Units	$/Suction Group		$5,460

- Industrial Plant

Item	Description	Source	Units	Qty	Cost ea.	Contractor	Price
	Equipment						
1	Programmable Automation Controller and Backplate	Opto22	Per Job	1	$762	0.34	$1,150
2	Additional PLC IO	Opto22	Per Job	1	$348	0.34	$525
3	Temperature Sensors	Source Refrigeration	Sensors	5	$270	0.34	$2,038
4	Suction Pressure Transducer	Sporlan	Per Sensor	1	$100	0.34	$151
5	**Materials**						
6	Wiring materials for temperature sensors	Estimate		1	$1,000		$1,000
7	**Labor and Subcontracts**						
8							
9	Engineering, Drawings, Project Management	Estimate	Person-hrs	16	$95		$1,520
10	Install new controller	Estimate	Person-hrs	8	$90		$720
11	Installation labor for sensors and cabling	Estimate	Person-hrs	15	$90		$1,350
12	Programming, calibration and fine-tuning labor	Estimate	Person-hrs	32	$115		$3,680
13	**Others**						
14	Taxes and Permits		%		0%		$0
15	Contingency Costs		%		5%		$607
				Total			$12,742
				Total Capacity or Size	Per Suction Group		1.0
				Costing Units	$/Suction Group		$12,742

Measure 7: Floating Head Pressure

Measure Description

Add controls and hardware to commercial multiplex and industrial refrigeration systems to float head pressure to 70°F SCT when conditions permit. Additional DEER measures add variable-setpoint (ambient following) control requirements and variable speed condenser fan control.

Measure Type: Retrofit

Base Case by Vintage:

- < 1978: Fixed SCT setpoint at 90°F
- 1978-1991: Fixed SCT setpoint at 90°F
- 1992-2000: Fixed SCT setpoint at 90°F
- 2000-2005: Fixed SCT setpoint at 85°F
- 2005: Fixed SCT setpoint at 85°F
- New-Construction Code Minimums:
    - 2014 California Title 24 codes mandate floating head pressure to 70°F with ambient following controls and variable speed fans for commercial systems consisting of multiple compressors, and refrigerated warehouse systems serving refrigerated spaces that are greater than 3,000 square feet of floor space.

Changes to Measure Subdivisions

None

Measure Notes

For retrofits, the utility workpapers for this measure state that projects that only reprogram a controller do not qualify as a measure and that new hardware must be installed. The utility workpapers do not quantify the extent of the 'new hardware' requirement, but based on the statement that reprogramming a controller does not qualify as a measure, it was interpreted that an upgrade to centralized refrigeration control was the basis for all of the floating head pressure measures.

For establishing measure cost, it was assumed that only controls upgrades were required, although some systems will need piping and/or compressor changes to safely float head pressure to 70°F. The float limit on some industrial systems with screw compressors is limited by the compressors' oil separator size and/or oil cooling method. Additional care must also be given to systems with hot gas evaporator coil defrost to ensure there is adequate heat to effectively defrost the coils during low-head conditions. Back-flooding valves may require adjustment or replacement, particularly on commercial systems. Finally, there may also be float limitations related to the distance from the liquid receiver vessel to the loads. Hardware upgrade costs for these contingencies were not included in the measure cost buildup, and could potentially be substantial, possibly even making the measure(s) cost-prohibitive.

Similar to the floating suction pressure measure, controls vendors indicated that it is difficult to isolate the cost for this measure. For retrofits, condenser fan control logic is often included in a comprehensive controls upgrade which may include any combination of other measures, including floating suction pressure, and variable-speed air unit control. The incremental cost of each measure would be much less than the sum total of each individual DEER measure cost due to redundant hardware requirements. Although new central controllers were included in the measure cost buildup, care was given to include only the installation and programming labor related to condenser control—the labor costs for switching to centralized compressor control are not included in the cost buildup.

Measure Description and DEER Database ID	Cost Analysis Subdivisions	Costing Basis	Costing Method
Floating head pressure control to 70°F SCT with fixed SCT setpoint and fan cycling D03-221 (Air-Cooled Commercial Systems) D03-222 (Evaporative-Cooled Commercial Systems) D03-307 (Evaporative-Cooled Industrial Systems)	Parallel Supermarket System, retrofit	Parallel supermarket system, condenser fan control based on local pressure switches (fan cycling on air-cooled condenser, 2-speed fan on evaporative condenser). Air-cooled condenser assumed to be 5-fan unit, fans <1 HP and <460V. Evaporative condenser assumed to be 20HP, <460V	Build up costs consisting of hardware, installation, and contractor mark-ups.
	Industrial Plant, retrofit	Ammonia industrial system, condenser fan cycling based on pressure switches	Build up costs consisting of hardware, installation, and contractor mark-ups.
Floating head pressure control to 70°F SCT with ambient-following SCT setpoint and fan cycling D03-223 (Air-cooled commercial systems) D03-224 (Evaporative-cooled commercial systems) D03-308 (Evaporative-cooled industrial systems)	Parallel Supermarket System, retrofit	Parallel supermarket system, condenser fan control based on local pressure switches (fan cycling on air-cooled condenser, 2-speed fan on evaporative condenser). Air-cooled condenser assumed to be 5-fan unit, fans <1 HP and <460V. Evaporative condenser assumed to be 20HP, <460V	Build up costs consisting of hardware, installation, and contractor mark-ups.
	Industrial Plant, retrofit	Ammonia industrial system, condenser fan cycling based on pressure switches	Build up costs consisting of hardware, installation, and contractor mark-ups.
Floating head pressure control to 70°F SCT with ambient-following SCT setpoint and variable-speed fan control	Parallel Supermarket System, retrofit	Parallel supermarket system, condenser fan control based on local pressure switches (fan cycling on air-cooled condenser, 2-speed fan on evaporative	Build up costs consisting of hardware, installation, and contractor mark-ups.

D03-225 (Air-cooled commercial systems) D03-226 (Evaporative-cooled commercial systems) D03-309 (evaporative-cooled industrial systems)		condenser). Air-cooled condenser assumed to be 5-fan unit, fans <1 HP and <460V. Evaporative condenser assumed to be 20HP, <460V	
	Industrial Plant, retrofit	Ammonia industrial system, condenser fan cycling based on pressure switches	Build up costs consisting of hardware, installation, and contractor mark-ups.

Measure Cost Buildups

- Supermarket system, retrofit, floating head pressure, fixed setpoint, fan cycling, air-cooled condenser

Item	Description	Source	Units	Qty	Cost ea.	Contractor Margin	Price
	Equipment						
1	New microprocessor controller	Aztec Engineering	Controller	1	$1,750	0.34	$2,642
2	Additional IO Card	Aztec Engineering	IO Card	1	$350	0.34	$530
3	**Materials**						
4	Pressure Transducer 0-500 psig	Estimate	Xducer	1	$186		$186
5	Wiring materials for new controller	Estimate		1	$100		$100
6	Wiring/Conduit for new pressure transducer	Estimate		1	$50		$50
7	Installation Materials	Estimate		1	$500		$500
8	**Labor and Subcontracts**						
9	Engineering, Drawings, Project Management	Estimate	Person-hrs	16	$95		$1,520
10	Install new controller	Estimate	Person-hrs	8	$90		$720
11	Installation labor for pressure transducer and cabling	Estimate	Person-hrs	2	$90		$180
12	Programming, start-up and fine-tuning labor	Estimate	Person-hrs	16	$115		$1,840
13							
14	**Others**						
15	Taxes and Permits		%		0%		$0
16	Contingency Costs		%		5%		$413
				Total			$8,682
				Total Capacity or Size	Per Discharge Group		1.0
				Costing Units	$/Discharge Grp		$8,682

- Supermarket system, retrofit, floating head pressure, fixed setpoint, 2-speed fan, evaporative condenser

Item	Description	Source	Units	Qty	Cost ea.	Contractor	Price
	Equipment						
1	New microprocessor controller	Aztec Engineering	Controller	1	$1,750	0.34	$2,642
2	Additional IO Card	Aztec Engineering	IO Card	1	$350	0.34	$530
3	**Materials**						
4	Pressure Transducer 0-500 psig	Estimate	Xducer	1	$186		$186
5	Wiring materials for new controller	Estimate		1	$100		$100
6	Wiring/Conduit for new pressure transduceer	Estimate		1	$50		$50
7	Installation Materials	Estimate		1	$500		$500
8	**Labor and Subcontracts**						
9	Engineering, Drawings, Project Management	Estimate	Person-hrs	16	$95		$1,520
10	Install new controller	Estimate	Person-hrs	8	$90		$720
11	Installation labor for pressure transducer and cabling	Estimate	Person-hrs	2	$90		$180
12	Programming, start-up and fine-tuning labor	Estimate	Person-hrs	16	$115		$1,840
13							
14	**Others**						
15	Taxes and Permits		%		0%		$0
16	Contingency Costs		%		5%		$413
				Total			$8,682
				Total Capacity or Size	Per Discharge Group		1.0
				Costing Units	$/Discharge Grp		$8,682

- Supermarket system, retrofit, floating head pressure, variable setpoint (drybulb following), fan cycling, air-cooled condenser

Item	Description	Source	Units	Qty	Cost ea.	Contractor	Price
	Equipment						
1	New microprocessor controller	Aztec Engineering	Controller	1	$1,750	0.34	$2,642
2	Additional IO Card	Aztec Engineering	IO Card	1	$350	0.34	$530
3	Ambient DBT Sensor and Outdoor Enclosure	Estimate		1	$100	0.34	$152
4	Pressure Transducer 0-500 psig	Estimate		1	$186	0.34	$282
5	**Materials**						
6	Wiring materials for new controller	Estimate		1	$100		$100
7	Wiring/Conduit for new pressure transducer	Estimate		1	$100		$100
8	Wiring/Conduit for ambient sensor	Estimate		1	$100		$100
9	Installation Materials	Estimate		1	$500		$500
10	**Labor and Subcontracts**						
11	Engineering, Drawings, Project Management	Estimate	Person-hrs	16	$95		$1,520
12	Install new controller	Estimate	Person-hrs	8	$90		$720
13	Installation labor for pressure transducer and cabling	Estimate	Person-hrs	2	$90		$180
14	Installation labor for ambient sensor	Estimate	Person-hrs	2	$90		$180
15	Programming, start-up and fine-tuning labor	Estimate	Person-hrs	16	$115		$1,840
16							
17	**Others**						
18	Taxes and Permits		%		0%		$0
19	Contingency Costs		%		5%		$442
				Total			$9,289
				Total Capacity or Size	Per Discharge Group		1.0
				Costing Units	$/Discharge Grp		$9,289

- Supermarket system, floating head pressure, variable setpoint (wetbulb following), two-speed fan control, evaporative condenser

Item	Description	Source	Units	Qty	Cost ea.	Contractor Margin	Price
	Equipment						
1	New microprocessor controller	Aztec Engineering	Controller	1	$1,750	0.34	$2,642
2	Additional IO Card	Aztec Engineering	IO Card	1	$350	0.34	$530
3	Ambient WBT and RH Sensor and Outdoor Enclosure	GE Sensing		1	$300	0.34	$455
4	Pressure Transducer 0-500 psig	Estimate	Xducer	1	$186	0.34	$282
5	**Materials**						
6	Wiring materials for new controller	Estimate		1	$100		$100
7	Wiring/Conduit for new pressure transduceer	Estimate		1	$100		$100
8	Wiring/Conduit for ambient sensor	Estimate		1	$100		$100
9	Installation Materials	Estimate		1	$500		$500
8	**Labor and Subcontracts**						
9	Engineering, Drawings, Project Management	Estimate	Person-hrs	16	$95		$1,520
10	Install new controller	Estimate	Person-hrs	8	$90		$720
11	Installation labor for pressure transducer and cabling	Estimate	Person-hrs	2	$90		$180
12	Installation labor for ambient sensor	Estimate	Person-hrs	2	$90		$180
13	Programming, start-up and fine-tuning labor	Estimate	Person-hrs	16	$115		$1,840
14							
15	**Others**						
16	Taxes and Permits		%		0%		$0
17	Contingency Costs		%		5%		$457
				Total			$9,607
				Total Capacity or Size	Per Discharge Group		1.0
				Costing Units	$/Discharge Grp		$9,607

- Supermarket system, floating head pressure, variable setpoint (drybulb following), variable speed fan control, air-cooled condenser

Item	Description	Source	Units	Qty	Cost ea.	Contractor	Price
	Equipment						
1	New microprocessor controller	Aztec Engineering	Controller	1	$1,750	0.34	$2,642
1	ABB VFD, 10 HP	Western Switches	per VFD	1	$706	0.34	$1,066
2	Additional IO Card	Aztec Engineering	IO Card	1	$350	0.34	$530
3	Panel Materials	Estimate		1	$640	0.34	$970
4	Ambient DBT Sensor and Outdoor Enclosure	Estimate		1	$100	0.34	$152
5	Pressure Transducer 0-500 psig	Estimate		1	$186	0.34	$282
6	**Materials**						
7	Wiring and installation materials	Estimate		1	$600		$600
8	**Labor and Subcontracts**						
9	Engineering, Drawings, Project Management	Estimate	hr	16	$95		$1,520
11	Panel Fabrication	Estimate	hr	20	$60		$1,200
10	Panel Installation	Estimate	hr	20	$90		$1,800
11	EMS Programming, fine-tuning	Estimate	hr	24	$115		$2,760
12	Installation labor for pressure transducer and cabling	Estimate	hr	2	$90		$180
13	Installation labor for ambient sensor	Estimate	hr	2	$90		$180
12	**Others**						
13	Taxes and Permits		%		0%		$0
14	Contingency Costs		%		5%		$543.98
				Total			$14,425
				Total Capacity or Size	Per Discharge Group		1
				Costing Units	$/Discharge Grp		$14,425

- Supermarket system, floating head pressure, variable setpoint (wetbulb-following), variable speed fan control, evaporative condenser

Item	Description	Source	Units	Qty	Cost ea.	Contractor Margin	Price
	Equipment						
1	New microprocessor controller	Aztec Engineering	Controlle	1	$1,750	0.34	$2,642
2	ABB VFD, 20 HP	Western Switches	per VFD	1	$1,266	0.34	$1,911
3	Additional IO Card	Aztec Engineering	IO Card	1	$350	0.34	$530
4	Panel Installation Materials	Estimate		1	$640	0.34	$970
5	Ambient WBT and RH Sensor and Outdoor Enclosure	GE Sensing		1	$300	0.34	$455
6	Pressure Transducer 0-500 psig	Estimate		1	$186	0.34	$282
7	**Materials**						
8	Wiring installation materials	Estimate		1	$600		$600
9	**Labor and Subcontracts**						
10	Engineering, Drawings, Project Management	Estimate	hr	16	$95		$1,520
11	Panel Fabrication	Estimate	hr	20	$60		$1,200
12	Panel Installation	Estimate	hr	20	$90		$1,800
13	EMS Programming, fine-tuning	Estimate	hr	24	$115		$2,760
14	Installation labor for pressure transducer and cabling	Estimate	hr	2	$90		$180
15	Installation labor for ambient sensor	Estimate	hr	2	$90		$180
16	**Others**						
17	Taxes and Permits		%		0%		$0
18	Contingency Costs		%		5%		$601.40
				Total			$15,631
				Total Capacity or Size	Per Discharge Group		1
				Costing Units	$/Discharge Grp		$15,631

- Industrial system, floating head pressure, fixed setpoint, fan cycling control, evaporative condenser

Item	Description	Source	Units	Qty	Cost ea.	Contractor Margin	Price
	Equipment						
1	Programmable Automation Controller and Backplate	Opto22	Per Job	1	$762	0.34	$1,150
2	Additional PLC IO	Opto22	Per Job	1	$348	0.34	$525
3	**Materials**						
4	Pressure Transducer 0-500 psig	Estimate	Xducer	1	$186		$186
5	Wiring materials for new controller	Estimate		1	$100		$100
6	Wiring/Conduit for new pressure transduceer	Estimate		1	$50		$50
7	**Labor and Subcontracts**						
8	Engineering, Drawings, Project Management	Estimate	Person-hrs	16	$95		$1,520
9	Install new controller	Estimate	Person-hrs	8	$90		$720
10	Installation labor for pressure transducer and cabling	Estimate	Person-hrs	2	$90		$180
11	Programming, start-up and fine-tuning labor	Estimate	Person-hrs	16	$115		$1,840
12							
13	**Others**						
14	Taxes and Permits		%		0%		$0
15	Contingency Costs		%		5%		$314
				Total			$6,586
				Total Capacity or Size	Per Discharge Group		1.0
				Costing Units	$/Discharge Grp		$6,586

- Industrial system, floating head pressure, variable setpoint (wetbulb-following), fan cycling control, evaporative condenser

Item	Description	Source	Units	Qty	Cost ea.	Contractor Margin	Price
	Equipment						
1	Programmable Automation Controller and Backplate	Opto22	Per Job	1	$762	0.34	$1,150
2	Additional PLC IO	Opto22	Per Job	1	$348	0.34	$525
3	Ambient WBT and RH Sensor and Outdoor Enclosure	GE Sensing		1	$300	0.34	$455
4	Pressure Transducer 0-500 psig	Estimate	Xducer	1	$186	0.34	$282
5	**Materials**						
6	Wiring materials for new controller	Estimate		1	$100		$100
7	Wiring/Conduit for new pressure transduceer	Estimate		1	$100		$100
8	Wiring/Conduit for ambient sensor	Estimate		1	$100		$100
8	**Labor and Subcontracts**						
9	Engineering, Drawings, Project Management	Estimate	Person-hrs	16	$95		$1,520
10	Install new controller	Estimate	Person-hrs	8	$90		$720
11	Installation labor for pressure transducer and cabling	Estimate	Person-hrs	2	$90		$180
12	Installation labor for ambient sensor	Estimate	Person-hrs	2	$90		$180
13	Programming, start-up and fine-tuning labor	Estimate	Person-hrs	16	$115		$1,840
14							
15	**Others**						
16	Taxes and Permits		%		0%		$0
17	Contingency Costs		%		5%		$358
		Total					$7,510
		Total Capacity or Size			Per Discharge Group		1.0
		Costing Units			$/Discharge Grp		$7,510

- Industrial system, floating head pressure, variable setpoint (wetbulb-following), variable speed fan control, evaporative condenser

Item	Description	Source	Units	Qty	Cost ea.	Contractor Margin	Price
	Equipment						
1	Programmable Automation Controller and Backplate	Opto22	Per Job	1	$762	0.34	$1,150
2	ABB VFD, 20 HP	Western Switches	per VFD	1	$1,266	0.34	$1,911
3	Additional PLC IO	Opto22	Per Job	1	$348	0.34	$525
4	Panel Installation Materials	Estimate		1	$640	0.34	$970
5	Ambient WBT and RH Sensor and Outdoor Enclosure	GE Sensing		1	$300	0.34	$455
6	Pressure Transducer 0-500 psig	Estimate		1	$186	0.34	$282
7	**Materials**						
8	Wiring installation materials	Estimate		1	$600		$600
9	**Labor and Subcontracts**						
10	Engineering, Drawings, Project Management	Estimate	hr	16	$95		$1,520
11	Panel Fabrication	Estimate	hr	20	$60		$1,200
12	Panel Installation	Estimate	hr	20	$90		$1,800
13	EMS Programming, fine-tuning	Estimate	hr	24	$115		$2,760
14	Installation labor for pressure transducer and cabling	Estimate	hr	2	$90		$180
15	Installation labor for ambient sensor	Estimate	hr	2	$90		$180
16	**Others**						
17	Taxes and Permits		%		0%		$0
18	Contingency Costs		%		5%		$601.16
		Total					$14,135
		Total Capacity or Size			Per Discharge Group		1
		Costing Units			$/Discharge Grp		$14,135

Narratives from Industry

Source	Narrative
Aztec Energy	Scope of work would be to upgrade to a Danfoss controller (AKC-255 minimum, can also use 355), identify lowest loads needing sensors, install them and run wire/conduit, and tune system. Hard to tell what the end-user cost is--it varies project to project. Aztec mainly does retrofits/remodels, cost is usually $30-$60 K, but scope of project is usually multiple racks and is not limited to FSP. Greg said cost to end-user for Danfoss controller is $1,500-$2,000 depending on who the customer is
Source Refrigeration	$270 per temp sensor, programming and fine-tuning the refrigeration system controls $2500, and follow up visits to the job site for monitoring the working of the controls and applying fixes if needed $1,250 per visit. Travel costs would have to be passed through at cost.

Measure 8: LED Display Case Lights

Measure Description

Replace pin-based halogen T12 and T8 lighting systems in both reach-in door refrigerated display cases and open upright refrigerated display cases with new linear LED light bar luminaires.

Measure Type: Retrofit

Base Case by Vintage:

- < 1978: T12/T8
- 1978-1991: T12/T8
- 1992-2000: T12/T8
- 2000-2005: T12/T8
- 2005: T8
- New-Construction Code Minimums:
    - Federal requirements for refrigerated display cases impose limits on the total daily allowed energy usage by these fixtures. It is accepted in the industry that the federal requirements inherently limit new display cases to using LED lamps in reach-in door cases, and EC fan motors in both LT reach-in door cases and open MT cases.

Changes to Measure Subdivisions

Not applicable; LED display case lights are not currently in the DEER database.

Measure Notes

Vendors and end-users noted that the cost for this measure is in a state of transition, as manufacturing capacity is starting to match market demand and the cost for technology matures.

One end-user noted that the labor to install the lights is a significant source of measure cost, since every light vendor has a different receptacle and attachment configuration to the mullion bulkhead that has to be re-wired. Another vendor noted the opposite, saying that their lights are much easier to replace since the light backs are magnetized and the old light fixtures just pop off and the new ones pop on. The conclusion is that the labor cost can vary significantly, based on the choice of light vendor and the brand of existing display case.

For medium-temperature upright cases such as produce cases, there are sometimes produce misting systems that would block the light if brackets are not installed to lower the light mounting position, at additional material and installation labor cost.

One end-user noted that the measure requires a significant investment in labor since either the end-user or the contractor has to unload the product from the case, store it for the duration of the retrofit, and re-stock the case afterwards. Only one end-user noted that this was an issue, and it can presumably be avoided in most situations.

Installers indicated that they do not fine tune the refrigeration system after the lights are replaced as the overall reduction in case load is relatively small compared to the overall rack load.

Measure Description and DEER Database ID	Cost Analysis Subdivisions	Costing Basis	Costing Method
LED lights in display cases (no ID in current DEER database)	LT reach-in cases, retrofit	1 lineup (62 doors) of LT reach-in door, 1 LED light fixture per mullion plus one LED fixture at each end.	Build up costs based on LED fixture hardware costs, installation labor, taxes, contractor markup. Verify with contractor estimates
	MT open upright case, retrofit	1 lineup (124 ft) of MT deli case, 2x shelf fixtures, 1x nose fixture, 1x canopy fixture	Build up costs based on LED fixture hardware costs, installation labor, and contractor markup. Verify with contractor estimates

Measure Cost Build-Up

- Door Cases

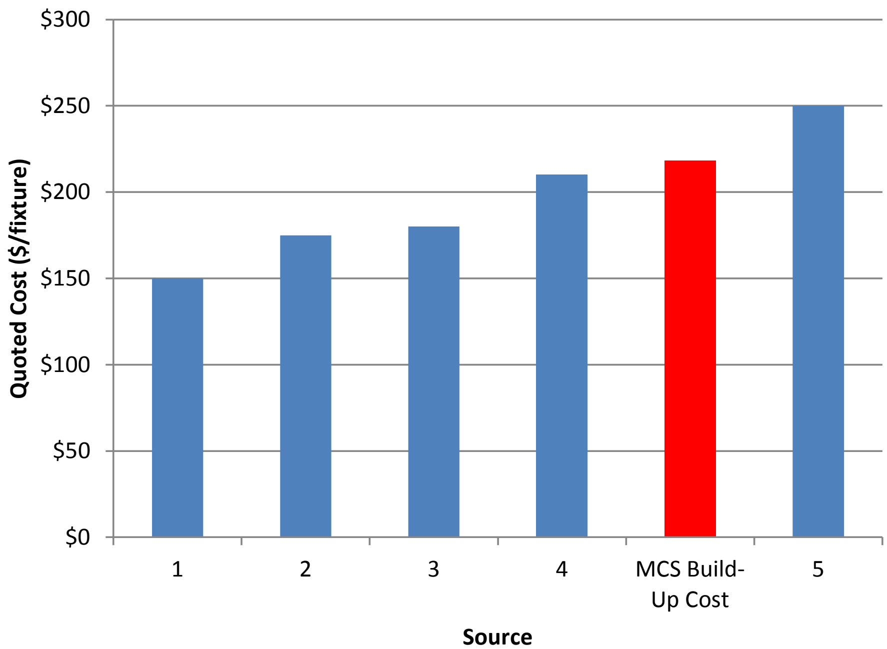
Item	Description	Source	Units	Qty	Cost ea.	Contractor Margin	Price
	Equipment						
1	Center mullion light	Reidco	lamp	61	$103	0.34	$9,439
2	End mullion light	Reidco	lamp	2	$80	0.34	$242
3	Power Source and Controller (one per case)	Reidco	pwr src	13	$63	0.34	$1,236
4	**Materials**						
5	Installation materials	Estimate		1	$300		$300
6	**Labor and Subcontracts**						
7	Engineering	Estimate	Person-Hrs	4	$95		$380
8	Installation Labor	Estimate	Person-Hrs	25	$60		$1,500
9	**Others**						
10	Taxes and Permits		%		0%		$0
11	Contingency Costs		%		5%		$654.86
				Total			$13,752
				Total Capacity or Size	Fixtures		63
				Costing Units	$/fixture		$218.3

- Open Cases

Item	Description	Source	Units	Qty	Cost ea.	Contractor Margin	Price
	Equipment						
1	LED lamp	Hussmann	lamp	100	$135	0.34	$20,381
2	Power Source and Controller (one per case)	Reidco	pwr src	13	$63	0.34	$1,236
3	**Materials**						
4	Installation materials	Estimate		1	$300		$300
5	**Labor and Subcontracts**						
6	Engineering	Estimate	Person-Hrs	4	$95		$380
7	Installation Labor	Hussmann	Person-Hrs	25	$60		$1,500
8	**Others**						
9	Taxes and Permits		%		0%		$0
10	Contingency Costs		%		5%		$1,190
				Total			$24,987
				Total Capacity or Size	Lamps		100
				Costing Units	$/lamp		$249.9

Benchmark Validation

Vendor Quote	Source	Price/Fixture	Notes
1	Source Refrigeration	$150	4' fixture cost with installation
2	DC Engineering	$175	Turn-key retrofit cost per fixture
3	Source Refrigeration	$180	5' fixture cost with installation
4	Source Refrigeration	$210	6' fixture cost with installation
MCS Cost Buildup, Door Case		**$218**	
MCS Cost Buildup, Open Case		**$250**	
5	Energy Wise America	$250	Turn-key retrofit cost per fixture. Energy Wise admits that this may be an out-of-date cost that doesn't reflect that LED technology has gotten cheaper



Measure 9: High-Efficiency Fan Motors

Measure Description

Replace shaded pole or permanent split capacitor (PSC) motors on walk-in and display case evaporator coils with electronically-commutated (EC motors)

Measure Type: Retrofit, Replace-on-burnout

Base Case by Vintage:

- < 1978: Shaded pole motors
- 1978-1991: Shaded pole motors
- 1992-2000: Shaded pole motors
- 2000-2005: Shaded pole motors
- 2005: Permanent split capacitor (PSC) motors
- New-Construction Code Minimums:
    - Federal legislation HR6 - Energy Independence and Security Act (EISA) of 2009 requires all walk-in evaporator fan motors less than 1 HP to be either EC or AC induction motors
    - California Title 20 codes are same as EISA regulations
    - Federal requirements for refrigerated display cases impose limits on the total daily allowed energy usage by these fixtures. It is accepted in the industry that the federal requirements inherently limit new display cases to using LED lamps in reach-in door cases, and EC fan motors in both LT reach-in door cases and open MT cases.

Changes to Measure Subdivisions

None

Measure Notes

Measure Description and DEER Database ID	Cost Analysis Subdivisions	Costing Basis	Costing Method
Substitute high-efficiency EC motors for permanent split capacitor (PSC) motors on walk-in unit cooler fans D03-202	Walk-In, Retrofit or replace-on-burnout	Walk-in cooler, two 2-fan unit coolers, 1/15 HP motors. Assume drop-in replacement	Build up costs consisting of hardware, installation, and contractor mark-ups. Verify with contractor estimates.
Substitute high-efficiency EC motors for permanent split capacitor (PSC)	Reach-In Display Case, Retrofit or	124 feet (62 door) LT reach-in display case lineup with 1/60 HP fan motors, assume 1 fan motor per door (62 motors). Assume	Build up costs consisting of hardware, installation, and contractor mark-ups. Verify with contractor

motors refrigerated display case fans D03-203	replace-on-burnout	store handles emptying/re-stocking the display case	estimates.
	Open Display Case, Retrofit or Replace-on-burnout	60 feet open MT multi-deck deli display case with 1/60 HP fan motors, assume 3 fans per 12-ft case (15 motors). Assume store handles emptying/re-stocking the display case	Build up costs consisting of hardware, installation, and contractor mark-ups. Verify with contractor estimates.

- Walk-in fan motors

Item	Description	Source	Units	Qty	Cost ea.	Contractor Margin	Price
	Equipment						
1	1/15 or 1/20 HP, 2-speed	Frigitek	Motor	4	$147.10		
2	Brushless DC Motor, ECM,1/15 HP, 1550 rpm, 115 V	Grainger	Motor	4	$141.75		
3	Brushless DC Motor, ECM,1/15 HP, 1550 rpm, 208-230 V	Grainger	Motor	4	$140.62		
4	Brushless DC Motor, ECM,1/15 HP, 1550 rpm, 115 V	Sierra Business Council	Motor	4	$169.86		
5	Average			4	$149.83	0.34	$905
6	**Materials**						
7	None. Assume drop-in replacement						$0
8	**Labor and Subcontracts**						
9	Installation Labor	Estimate	person-hrs	2	$60		$120
10	**Others**						
11	Taxes and Permits		%		0%		$0
12	Contingency Costs		%		5%		$51
		Total					$1,076
		Total Capacity or Size			Per Motor		4
		Costing Units			$/Motor		$269.01

- Door display case fan motors

Item	Description	Source	Units	Qty	Cost ea.	Contractor Margin	Price
	Equipment						
1	Brushless DC Motor, ECM, 1/60 HP, 1550 rpm	Grainger	Motor	62	$79		
2	Brushless DC Motor, ECM, 4-12 Watt/120 V	Sierra Business Council	Motor	62	$83		
3	Brushless DC Motor, ECM, 4-12 Watt/240 V	Sierra Business Council	Motor	62	$95		
4	Brushless DC Motor, ECM, 16 Watt/120 V	Sierra Business Council	Motor	62	$88		
5	Brushless DC Motor, ECM, 16 Watt/240 V	Sierra Business Council	Motor	62	$99		
6	Average		Motor	62	$81.09	0.34	$7,590
7	**Materials**						
8	None. Assume drop-in replacement						$0
9	**Labor and Subcontracts**						
10	Installation Labor	Estimate	person-hours	10	$60		$620
11	Labor to Load/Unload Case	Estimate	person-hours	12	$8		$99
12	**Others**						
13	Taxes and Permits		%		0%		$0
14	Contingency Costs		%		5%		$415.44
		Total					$8,724
		Total Capacity or Size			Per Motor		62
		Costing Units			$/Motor		$140.71

- Open upright display case fan motors

Item	Description	Source	Units	Qty	Cost ea.	Contractor Margin	Price
	Equipment						
1	Brushless DC Motor, ECM, 1/60 HP, 1550 rpm	Grainger	Motor	15	$79		
2	Brushless DC Motor, ECM, 4-12 Watt/120 V	Sierra Business Council	Motor	15	$83		
3	Brushless DC Motor, ECM, 4-12 Watt/240 V	Sierra Business Council	Motor	15	$95		
4	Brushless DC Motor, ECM, 16 Watt/120 V	Sierra Business Council	Motor	15	$88		
5	Brushless DC Motor, ECM, 16 Watt/240 V	Sierra Business Council	Motor	15	$99		
6	Average		Motor	15	$81.09	0.34	$1,836
7	**Materials**						
8	None. Assume drop-in replacement						$0
9	**Labor and Subcontracts**						
10	Installation Labor	Estimate	person-hrs	3	$60		$150
11	Labor to Load/Unload Case	Estimate	person-hours	5	$8		$40
12	**Others**						
13	Taxes and Permits		%		0%		$0
14	Contingency Costs		%		5%		$99
				Total			$2,125
				Total Capacity or Size	Per Motor		15
				Costing Units	$/Motor		$141.70

Appendix D

Joint HVAC Contractor Survey Details

D.1 Survey Script (Measure Cost Study Battery)

D.2 Sample Frame Development Memorandum

D.3 Sample Design and Final Disposition

D.4 Expansion Weights

D.1 Survey Script (Measure Cost Study Battery)

2010-2012 CPUC JOINT HVAC CONTRACTOR SURVEY

MEASURE COST STUDY

SCREENER Next, I'd like to know if you are knowledgeable on the labor-hours required and general costs associated with a installation on a AC unit for a commercial customer. Would you be able to comment on this topic?

1	Yes	Qintro
2	IF NO, ASK IF ANOTHER RESPONDENT AT COMPANY MAY KNOW. RECORD	WC10
88	Refused	WC10
99	Don't Know	WC10

QIntro Now I am going to ask you about the labor requirements and other costs associated with repairing or replacing certain HVAC equipment. For each of the following questions, assume that a pre-inspection has been completed and a work plan has already been developed.

The following questions apply to retrofitting a split DX or packaged DX system on a low rise, flat roof, commercial building.

COST_Q1 On average, how much does it cost to rent a crane to remove an old outdoor unit and install a new unit? Please exclude any costs related to required permits.

66	None	COST_Q2
77	Open - Numeric	COST_Q2
88	Refused	COST_Q2
99	Don't Know	COST_Q2

COST_Q2 On average, how many man-hours does it take to remove an old unit, assuming a crane is used for the removal? Please include time associated with pulling refrigerant out, disconnecting electrical and controls, disconnecting the unit from the curb, removal of the unit by crane, and taking the unit to the recycler.

66	None	COST_Q3
77	Open - Numeric	COST_Q3
88	Refused	COST_Q3
99	Don't Know	COST_Q3

COST_Q3 On average, what is the disposal fee for the old unit?

66	None	COST_Q4
77	Open - Numeric	COST_Q4
88	Refused	COST_Q4
99	Don't Know	COST_Q4

COST_Q4 On average, how many man-hours does it take to install a new 5 ton unit? Please include the time required for preparing the curb and installing new curb gaskets, moving the unit into place with the crane, attaching refrigerant piping, connecting electrical and gas as necessary, and connecting ductwork. Assume no new curb is required and no new screen is required to conceal the unit.

66	None	COST_Q5
77	Open - Numeric	COST_Q5
88	Refused	COST_Q5
99	Don't Know	COST_Q5

COST_Q5 On average, how many man-hours does it take to install a new 40 ton unit? Please include the time required for preparing the curb and installing new curb gaskets, moving the unit into place with the crane, attaching refrigerant piping, connecting electrical and gas as necessary, and connecting ductwork. Assume no new curb is required and no new screen is required to conceal the unit.

66	None	COST_Q9
77	Open - Numeric	COST_Q9
88	Refused	COST_Q9
99	Don't Know	COST_Q9

COST_Q9 On average, how many man-hours does it take to perform testing/commissioning on a newly installed 5 ton unit to ensure it is running properly? Please include time required for checking belt alignment, starting compressors and making sure pressure is correct, checking combustion efficiency (in the case of gas units), checking for air leaks in the ductwork, making sure amperage is in the acceptable range, and balancing air flow.

66	None	COST_Q10
77	Open - Numeric	COST_Q10
88	Refused	COST_Q10
99	Don't Know	COST_Q10

COST_Q10 On average, how many man-hours does it take to perform testing/commissioning on a newly installed 40 ton unit to ensure it is running properly? Please include time required for checking belt alignment, starting compressors and making sure pressure is correct, checking combustion efficiency (in the case of gas units), checking for air leaks in the ductwork, making sure amperage is in the acceptable range, and balancing air flow.

66	None	COST_Q11
77	Open - Numeric	COST_Q11
88	Refused	COST_Q11
99	Don't Know	COST_Q11

PTAC Intro: The following questions apply to retrofitting a 1-2 ton through-the-wall PTAC (P-TAC) unit in a hotel room. Assume like-for-like replacement of one PTAC unit with another of the same size.

COST_Q11 On average, how much does it cost to remove and dispose of the old unit? Please include the time required for removing the old unit from the wall sleeve and getting it to a recycler.

66	None	COST_Q12
77	Open - Numeric	COST_Q12
88	Refused	COST_Q12
99	Don't Know	COST_Q12

COST_Q12 On average, how long does it take to move the new unit into place and reconnect the wiring? Please include the time required for loading and transporting the new unit, installing it in the old sleeve, and reconnecting wiring. Exclude any time associated with thermostat or EMS.

66	None	COST_Q13
77	Open - Numeric	COST_Q13
88	Refused	COST_Q13
99	Don't Know	COST_Q13

QM Intro: The following questions apply to performance maintenance for a 5 ton outdoor condenser unit (split) or 5 ton packaged unit in accordance with ASHRAE ("Ash-ray") Standard 180. Assume a low rise commercial building with typical maintenance demands [and that any man-hours that typically overlap between refrigerant charging and coil cleaning are evenly split between these two measures].

COST_Q13 On average, how many man-hours does it take to perform basic maintenance on the unit without a refrigerant charge adjustment or coil cleaning? Please include the time required to check refrigerant charge, check belt alignment, change the filter, check level of coil fouling, and check the electric system.

66	None	COST_Q14
77	Open - Text	COST_Q14
88	Refused	COST_Q14
99	Don't Know	COST_Q14

COST_Q14 On average, how long does it take to correct a refrigerant undercharge or overcharge in terms of man hours per unit?

66	None	COST_Q15
77	Open - Text	COST_Q15
88	Refused	COST_Q15
99	Don't Know	COST_Q15

COST_Q15 On average, how long does it take to clean coils in terms of man-hours per unit? Please include the time required to clean the coils both on the inside and the outside.

66	None	WC10_1
77	Open - Text	WC10_1

88	Refused	WC10_1
99	Don't Know	WC10_1

D.2 Sample Frame Development Memorandum

Itron

Electric / Gas / Water
Information collection, analysis and application

Memo

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Date: August 14, 2013

To: Jean Shelton, Itron
Jarred Metoyer, DNV KEMA
Ralph Prahl, ED consultant
Pete Jacobs, ED consultant
Lisa Paulo, ED
Nils Strindberg, ED
Katie Wu, ED

From: Mike Ting, Itron

This memo presents a brief summary of the data sources and methods used to develop the proposed sample frame for the Joint HVAC Contractor Survey being prepared to address research needs for Work Orders 17 (Measure Cost), 24 (Commercial Market Share Tracking), and 32 (Small HVAC Impact).

The HVAC contractor sample frame was developed from two primary data sources: 1) the complete list of current C20 licensees in California from the California Contractor State License Board (CLSB), and 2) several InfoUSA sample pulls of NAICS codes covering HVAC contractors in California.

In California, a C20 license is required for any contractor that "fabricates, installs, maintains, services and repairs" warm-air heating, air-conditioning, and/or ventilation systems, with the CLSB acting as the licensing agency for the State.[1] In this sense, the list of current C20 licensees (referred to hereafter as the "CLSB frame") represents the complete population of HVAC contractors in California. Indeed, EMI obtained the CLSB frame to use as the population frame for an online survey of HVAC contractors developed and fielded by EMI and NMR on behalf of the IOUs in the fall of 2012. Through the WO32 team's coordination efforts with the IOUs (via

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[1] Source: California Code of Regulations, Title 16, Division 8, Article 3. Available at: http://www.cslb.ca.gov/GeneralInformation/Library/LicensingClassifications/C20WARMAIRHEATINGVENTILATINGANDAIRCONDITIONING.ASP

the HVAC PCG), the survey team requested access to the same CLSB frame, and the IOUs kindly provided the frame to Itron in Q1 2013.

This original CLSB frame contains personal names, company names, phone numbers, and mailing address for roughly 10,000 holders of active C20 licenses in California. Importantly, however, there are no variables available in original CLSB frame that could be used for post-weighting purposes. For the ED-led WOs, it was therefore necessary to backfill the CLSB frame with firmographic data from another source in order to develop a sample frame that would allow proper post-weighting of the survey results.

To do this, the survey team merged firmographic data provided by DNV-KEMA (via their subscription to InfoUSA) for several NAICS codes known to contain HVAC contractors. Conceptually, NAICS code 28322 (Plumbing, Heating, and Air-Conditioning Contractors) should contain all C20 licensees. In practice, however, NAICS codes are often inaccurate and/or out-of-date. Indeed, only ~25% of the records in the CLSB frame merged successfully against the InfoUSA pulls of NAICS 2382202 (AC Contractors), NAICS 23821007 (Electrical Contractors), and a variety of NAICS codes representing HVAC distributors. From previous DNV-KEMA efforts to identify HVAC equipment distributors in California (using InfoUSA sample pulls), the survey team identified at least three additional NAICS codes (238990, 81131001, 81141227) that also contain HVAC contractors. Using InfoUSA pulls of these additional NAICS codes and a data pull of the more general NAICS 23822, the survey team was able to merge an additional 25% of the records from the CLSB frame. In total, just over 50% of all records in the original CLSB frame (5,288 out of 10,486) were successfully backfilled with firmographic data, including number of employees and annual revenue. Table 1 below lists all of the NAICS codes that the survey team pulled and merged with the CLSB frame.

Table 1: NAICS codes used to merge against CLSB frame

NAICS	Description
28322	Plumbing, Heating, and Air-Conditioning Contractors
238990	All Other Specialty Trade Contractors
81131001	Commercial and Industrial Machinery and Equipment (except Automotive and Electronic) Repair and Maintenance
81141227	Appliance Repair and Maintenance

Due to the resource and calendar constraints faced by WO17, WO24, and WO32, rather than continue merging against additional NAICS codes (with a rapidly increasing marginal cost), the survey team then attempted to assess the representativeness of the "backfilled" CLSB frame. To do this, the survey team calculated frequency distributions of the number of employees and annual revenue in the backfilled CLSB and compared these against the corresponding frequency distributions in the "population" as represented by NAICS 28322.[2] Table 2 shows the results of this comparison.

Table 2: Comparison of frequency distributions (number of employees, annual revenues) between NAICS 28233 and backfilled CLSB frame

Firm Size (employees)	Number of Employees		Annual Revenues	
	NAICS 23822	Backfilled CLSB	NAICS 23822	Backfilled CLSB
1 to 4	63.8%	60.3%	17.6%	17.9%
5 to 9	20.7%	19.1%	17.2%	16.4%
10 to 19	7.5%	9.5%	12.4%	16.9%
20 to 49	5.2%	7.3%	19.6%	22.5%
50 to 99	1.9%	1.8%	12.8%	10.8%
100 to 249	0.7%	0.9%	12.0%	12.6%
250 to 499	0.1%	0.1%	3.5%	1.9%
500 to 999	0.0%	0.0%	1.4%	1.0%
1000 to 4999	0.0%	0.0%	0.9%	0.0%
5000 to 9999	0.0%	0.0%	2.6%	0.0%

As the table above shows, the relative distribution of firms by the number of employees and annual revenue in the backfilled CLSB frame very closely mirrors those in NAICS 28322. Given this result, along with the increasing marginal cost of further backfilling to the CLSB frame and the significant time and resource constraints faced by WOs 17, 24, and 32, the survey team strongly recommends moving forward with the current backfilled CLSB frame for purposes of the Joint HVAC contractor survey.

Due to the very limited amount of time available to field this survey within the respective project calendars of WO17, 24, and 32, the survey team requests an expedited review and approval of our recommended sample design. Please send any comments on the proposed sample frame to Mike Ting (michael.ting@itron.com), Jean Shelton (jean.shelton@itron.com), and Jarred Metoyer (jarred.metoyer@dnvkema.com) by email by COB Friday, August 16.

2 While NAICS 28322 is likely to be a super-set of all C20 licensees in California, it is the only NAICS code that, in theory, should contain all C20 licensees. Additionally, it is the only quasi-population frame available against which to assess the representativeness of the survey team's backfilled CLSB frame.

D.3 Sample Design and Final Disposition

HVAC Contractor Sample Design and Final Disposition

The number of contractors and the distribution of HVAC contractors by geographic location and number of employees are listed in Table 1. Following the matching of the C20 and InfoUSA data the HVAC contractor frame included 5,054 contractors. The number of contractors in the south exceeds the number of HVAC contractors in the north. This distribution is likely due in part to the higher air conditioning needs of the southern part of the state.

Table 1: HVAC Contractor Frame, Survey Quota, and Survey Completes

Region	Number of Employees	Frame of HVAC Contractors	HVAC Contractor Survey Quota	HVAC Contractor Survey Completes
NORTH	1 to 2	765	14	14
SOUTH	1 to 2	1044	19	20
NORTH	3 to 4	537	13	13
SOUTH	3 to 4	719	18	18
NORTH	5 to 9	443	11	12
SOUTH	5 to 9	541	13	14
NORTH	10 to 19	227	6	6
SOUTH	10 to 19	260	6	6
NORTH	20 to 49	142	4	4
SOUTH	20 to 49	229	6	6
NORTH	50 to 99	41	3	3
SOUTH	50 to 99	53	3	3
NORTH	100 to 249	24	3	3
SOUTH	100 to 249	21	3	1
NORTH	250 to 499	4	1	0
SOUTH	250 to 499	3	1	0
NORTH	500 to 999	1	1	0
SOUTH	500 to 999	0	0	0
Total		**5,054**	**125**	**123**

Survey Weighting and Completes

The 5,054 HVAC contractors in the matched C20 HVAC frame are disaggregated into stratum defined by geographic location (North and South or based on electric utility to PG&E for Northern California and SCE and SDG&E for Southern) and number of employees. Using these two variables, 14 strata are defined (see Table 1). Using these strata and a quota of 125 surveys, the quota are distributed across stratum. Table 1 also lists the number of survey completes by stratum. The Joint HVAC Contractor Survey completed 123 surveys, slightly oversampling some of the stratum with more contractors and not meeting the quota for some of the stratum with fewer contractors.

The weighting methodology was developed using revenue data from the matched C20 HVAC contractors in the population and information on the share of HVAC contractors' revenue derived from the sales or installations of HVAC; which was collected as part of the Joint HVAC Contractor Telephone Survey.

Using the information on the revenue for the population of HVAC contractors and information on each of the sampled site's HVAC revenues, the weight for a given contractor is developed using the following formula:

$$W_{ij} = \frac{Pop\ HVAC\ Rev_j * HVAC\ Rev_i}{\sum HVAC\ Rev_j}$$

Where

W_{ij} is the weight for HVAC contractor i in strata j,

$Pop\ HVAC\ Rev_j$ is the revenue for the population of HVAC contractors in stratum j,

$HVAC\ Rev_i$ is the HVAC revenue for contractor i in stratum j, and

$\sum HVAC\ Rev_j$ is the HVAC revenue for HVAC contractors interviewed as part of stratum j.

The weighting methodology weighs up an individual contractor's HVAC revenue to our best understanding of their share to the HVAC contractors' revenue in California.

Table 2: HVAC Contractor Frame, Survey Quota, and Survey Completes

Region	Number of Employees	Weight
NORTH	1 to 2	36.01
SOUTH	1 to 2	55.86
NORTH	3 to 4	18.28
SOUTH	3 to 4	15.94
NORTH	5 to 9	44.57
SOUTH	5 to 9	19.04
NORTH	10 to 19	21.99
SOUTH	10 to 19	22.24
NORTH	20 to 49	39.68
SOUTH	20 to 49	41.59
NORTH	50 to 99	11.82
SOUTH	50 to 99	16.63
NORTH	100 to 249	16.21
SOUTH	100 to 249	19.29

D.4 Expansion Weights

HVAC Contractor Survey Strata Weights

The 5,054 HVAC contractors in the matched C20 HVAC frame are disaggregated into stratum defined by geographic location (North and South or based on electric utility to PG&E for Northern California and SCE and SDG&E for Southern) and number of employees. Using these two variables, 14 strata are defined (see Table 1). Using these strata and a quota of 125 surveys, the quota are distributed across stratum. Table 1 also lists the number of survey completes by stratum. The Joint HVAC Contractor Survey completed 123 surveys, slightly oversampling some of the stratum with more contractors and not meeting the quota for some of the stratum with fewer contractors.

The weighting methodology was developed using revenue data from the matched C20 HVAC contractors in the population and information on the share of HVAC contractors' revenue derived from the sales or installations of HVAC; which was collected as part of the Joint HVAC Contractor Telephone Survey.

Using the information on the revenue for the population of HVAC contractors and information on each of the sampled site's HVAC revenues, the weight for a given contractor is developed using the following formula:

$$W_{ij} = \frac{Pop\ HVAC\ Rev_j * HVAC\ Rev_i}{\sum HVAC\ Rev_j}$$

Where

W_{ij} is the weight for HVAC contractor i in strata j,

$Pop\ HVAC\ Rev_j$ is the revenue for the population of HVAC contractors in stratum j,

$HVAC\ Rev_i$ is the HVAC revenue for contractor i in stratum j, and

$\sum HVAC\ Rev_j$ is the HVAC revenue for HVAC contractors interviewed as part of stratum j.

The weighting methodology weighs up an individual contractor's HVAC revenue to our best understanding of their share to the HVAC contractors' revenue in California. The final set of weights applied to the survey responses from each stratum are shown in Table 1 below.

Table 1: HVAC Contractor Survey Strata Weights

Region	Number of Employees	Weight
NORTH	1 to 2	36.01
SOUTH	1 to 2	55.86
NORTH	3 to 4	18.28
SOUTH	3 to 4	15.94
NORTH	5 to 9	44.57
SOUTH	5 to 9	19.04
NORTH	10 to 19	21.99
SOUTH	10 to 19	22.24
NORTH	20 to 49	39.68
SOUTH	20 to 49	41.59
NORTH	50 to 99	11.82
SOUTH	50 to 99	16.63
NORTH	100 to 249	16.21
SOUTH	100 to 249	19.29

Appendix E

Joint Lighting Contractor Survey Details

E.1 Survey Script (Measure Cost Study Battery)

E.2 Sample Frame Development Memorandum

E.3 Sample Design and Final Disposition

E.4 Expansion Weights

E.1 Survey Script (Measure Cost Study Battery)

MEASURE COST STUDY

MCSIntro

ASK ONLY IF PERF1 = 1; ELSE SKP TO LEDIntro
Now I am going to ask you about the average time required or retrofit certain lighting-related equipment. We are looking for an estimate of time in man-hours per item installed. Make sure if there is a helper or more than one person working on a job that you incorporate all man hours into your estimate. For each of the following questions, assume that a pre-inspection has been completed and a work plan has already been developed.

MCS1 On average, how long does it take to install wall-mounted occupancy sensors in terms of man-hours per sensor? Please include in the time required for: wiring, installation, programming, and commissioning.

66	None	MCS2
77	Open - Numeric	MCS2
88	Refused	MCS2
99	Don't Know	MCS2

MCS2 On average, how long does it take to install ceiling-mounted occupancy sensors in terms of man-hours per sensor? [IF NEEDED: Again, please include in the time required for: wiring, installation, programming, and commissioning.]

66	None	MCS3
77	Open - Numeric	MCS3
88	Refused	MCS3
99	Don't Know	MCS3

MCS3 On average, how long does it take to install fixture-integrated occupancy sensors inside existing fixtures in terms of man-hours per sensor. Please include the time required for: dismantling and re-assembling the fixture, in addition to wiring, installation, programming, and commissioning.

66	None	MCS4
77	Open - Numeric	MCS4
88	Refused	MCS4
99	Don't Know	MCS4

MCS6 On average, how long does it take to replace an HID with a T5 fixture in terms of man-hours per fixture where the fixtures are accessible with a ladder? Pleaase include the time required for: removal of existing fixture+lamp, decommissioning the old fixture, wiring the new fixture, installation of the new fixture, and commissioning.

66	None	MCS7
77	Open - Numeric	MCS7
88	Refused	MCS7
99	Don't Know	MCS7

MCS7 On average, how long does it take to replace an HID with a T5 fixture in terms of man-hours per fixture where the ceiling height <u>requires a lift instead of a ladder?</u> [IF NEEDED: Again, please include the time required for: removal of existing fixture + lamp, decommissioning the old fixture, wiring the new fixture, installation of the new fixture, and commissioning.]

66	None	MCS8
77	Open - Numeric	MCS8
88	Refused	MCS8
99	Don't Know	MCS8

MCS8 On average, how long does it take to replace a 4-ft T12 fixture with a T5 or T8 fixture in terms of man-hours per fixture where the fixtures are recessed in "T-bar Ceilings" and accessible with a ladder? Please include the time required for: removal of existing fixture+lamp+ballast, wiring the new fixture and ballast, installation, and commissioning.

66	None	MCS9
77	Open - Numeric	MCS9
88	Refused	MCS9

99	Don't Know	MCS9

MCS9 On average, how long does it take to replace a 4-ft T12 fixture with a T5 or T8 fixture in terms of man-hours per fixture where the fixtures are surface-mounted on "T-bar Ceilings" and accessible with a ladder? [IF NEEDED: Again, please include the time required for: removal of existing fixture+lamp+ballast, wiring the new fixture and ballast, installation, and commissioning.]

66	None	MCS10
77	Open - Numeric	MCS10
88	Refused	MCS10
99	Don't Know	MCS10

MCS10 On average, how long does it take to replace a low efficiency linear ballast with a high efficiency ballast in terms of man-hours per ballast where the fixtures are recessed in "T-bar Ceilings" and accessible with a ladder? Pleaase include the time required for: removal of existing ballast, wiring the new ballast, installation, and commissioning.

66	None	MCS11
77	Open - Numeric	MCS11
88	Refused	MCS11
99	Don't Know	MCS11

MCS11 On average, how long does it take to replace a low efficiency linear fluorescent ballast with high efficiency ballast in terms of man-hours per ballast in "high bay" ceilings where a lift is required? [IF NEEDED: Please include the time required for: removal of existing ballast, wiring the new ballast, installation, and commissioning.]

66	None	MCS12
77	Open - Numeric	MCS12
88	Refused	MCS12
99	Don't Know	MCS12

MCS12 On average, how long does it take to replace existing T8 lamps with new T8 lamps for 2-lamp fixtures recessed in "T-bar Ceilings" accessible with a ladder, in terms of man-hours per fixture? Please include the time required for: removal of existing lamps, installation of new lamps, and commissioning.

66	None	MCS13
77	Open - Numeric	MCS13
88	Refused	MCS13
99	Don't Know	MCS13

MCS13 On average, how long does it take to replace existing T8 lamps new T8 lamps for 2-lamp fixtures in "high bay" ceilings where a lift is required, in terms of man-hours per fixture. [IF NEEDED: Please include the time required for: removal of existing lamp, installation of new lamp, and commissioning.]

66	None	MCS14
77	Open - Numeric	MCS14
88	Refused	MCS14
99	Don't Know	MCS14

MCS14 On average, how long does it take to "de-lamp" a typical 3-lamp fixture in "T-bar Ceilings" accessible with a ladder, in terms of man-hours per fixture. Please include the time required for: removal of existing lamp and holders.

66	None	MCS15
77	Open - Numeric	MCS15
88	Refused	MCS15
99	Don't Know	MCS15

MCS15 On average, how long does it take to "de-lamp" a typical 3-lamp fixture in "High Bay Ceilings" where a lift is required in terms of man-hours per fixture. [IF NEEDED: Please include the time required for: removal of existing lamp and holders.]

66	None	MCS16
77	Open - Numeric	MCS16
88	Refused	MCS16
99	Don't Know	MCS16

MCS16 On average, how long does it take to prepare removed linear fluorescent lamps/ballasts/fixtures for disposal, in terms of man-hours per 100 lamps/fixtures/ballasts. Please include the time required for: collecting items for disposal, managing broken items, packaging, and arranging for pick-up. This estimate should not include the time it takes for the disposal companies to pick up and dispose of the equipment.

66	None	MCS17
77	Open - Numeric	MCS17
88	Refused	MCS17
99	Don't Know	MCS17

MCS17 Can you please provide us with the names of disposal companies you are familiar with? If you have any contact information, could you provide that to us as well?

66	None	LEDIntro
77	Open - Text	LEDIntro
88	Refused	LEDIntro
99	Don't Know	LEDIntro

E.2 Sample Frame Development Memorandum

Itron

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Information collection, analysis and application

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Memo

Date: March 20, 2013

To: Mike Ting, Itron
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From: Jean Shelton, Itron

This memo presents a brief summary of the data sources and rationale used to develop the sample frame for the Joint Lighting Contractor Survey being prepared to address research needs for Work Orders 17 (Measure Cost), 24 (Commercial Market Share Tracking), 29 (Nonresidential Downstream Lighting Impact), and 54 (LED Market Effects).

The contractor sample frame was developed from a D&B pull of California electrical contractors (NAICS code 238210). The original sample frame included 11,431 electrical contractor establishments that employ 92,115 individuals. The sample frame does not include corporate locations. The sample design was developed to census sample very large firms. Due to the census sampling, the seven largest contractors (500+ employees) were reviewed to ensure that they were electrical contractors. This review included a web search and concluded that four of these businesses were not electrical contractors.[1] These four large non-electrical contractor firms were removed from the sample frame. The final sample frame of electrical contractors from the D&B pull is described in Table 1. The data from the D&B pull have been characterized by the number of employees working for the contractor. The proposed sample distribution is based on the number of employees working for the contractor.

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[1] The four non-electrical contractor sites were: A carpet cleaner, a developer of communications and radar technologies, a software developer, and a voice over IP firm.

Table 1: Electrical Contractors in California And Proposed Quota Distribution

Electrical Contractors in California				
Number of Employees	**Number of Establishments**	**Sum of Employees**	**Share of Total Employment**	**Proposed Quota Points**
1 to 2	2,683	3,535	4%	0
3 to 4	5,062	17,353	20%	14
5 to 9	1,950	12,190	14%	21
10 to 19	932	11,254	13%	20
20 to 49	522	14,813	17%	25
50 to 99	191	11,453	13%	20
100 to 249	67	8,618	10%	14
250 to 499	17	4,854	5%	8
500 to 999	0	0	0%	0
1000 to 4999	3	4,300	5%	3
Total	11,427	88,370	100%	125

As Table 1 shows, the proposed quota distribution for lighting contractors does not include quota for firms with 1-2 employees. While these firms are numerous, they represent a small share of the number of employees in the electrical contractor frame (4%), they may be more difficult to contact, they may be electrical contractors that are not lighting specialists, and they are more likely to install residential lighting than commercial lighting. For these reasons, the team chose to allocate no quota to these very small contractors.

Overall, Itron and DNV KEMA feel that the sample frame will lead to the identification of lighting contractors who will meet the varied research objectives of WOs 17, 24, 29, and 54. Using the D&B electrical contractor frame will lead to the team dialing many contractors who are not eligible for our survey. The initial screening questions in the survey will work to characterize those electrical contractors who are eligible for our survey. Eliminating the very large contractors that do not pass a web review and not assigning quota for firms with 1-2 employees will also help to reduce some survey costs.

The annual sales and employee data available from the D&B data and the data collected as part of the telephone surveys will be used for post weighting the survey responses.

E.3 Sample Design and Final Disposition

Lighting Contractor Sample Design and Disposition

Information from a Dunn and Bradstreet extraction of electrical contractors was used to develop a lighting contractor frame representing the population of lighting contractors in California. The North American Industry Classification System or NAICS code for electrical contractor is 238210. The electrical contractor NAICs code was used to pull an electrical contractor frame within California. Table 1 lists the number of electrical contractors in the frame by their region and the number of employees at the location.

Using the electrical contractor frame and quota of 125 completed lighting contractor surveys, the team developed a quota for the lighting contractor surveys based on the contractor's geographical location (north/south) and the number of employees associated with the contractor. Table 1 presents the lighting contractor quota and the number of survey completes achieved.

Distinguishing lighting contractors from electrical contractors is the first set of screening questions in the survey. Survey respondents are asked the following three questions to determine if they are lighting contractors eligible for the lighting survey:

- Do you perform installations of lighting equipment for commercial and industrial customers in California?
- Do you sell lighting equipment to commercial and industrial customers, including multifamily residential facilities in California?
- Do you sell lighting to other contractors for installation in commercial and industrial facilities?

To continue with the lighting survey, the contractor had to respond affirmatively to at least one of the questions above. The survey tracked both the number of electrical contractors passing and not passing the lighting contractor screening questions by strata. This information is used to develop an estimate of the size of the lighting contractor population by strata. The size of the lighting contractor population is used to develop contractor weights.

Table 1: Electrical Contractor Frame and Lighting Contractor Quota and Survey Completes

Region	Number of Employees	Number of Electrical Contractors	Lighting Contractor Survey Quota	Lighting Contractor Surveys
North	1 to 2	1,111	0	0
South	1 to 2	1,417	0	0
North	3 to 4	2,078	6	8
South	3 to 4	3,001	8	10
North	5 to 9	707	10	11
South	5 to 9	1,008	11	11
North	10 to 19	318	8	8
South	10 to 19	490	12	12
North	20 to 49	201	11	9
South	20 to 49	219	14	13
North	50 to 99	67	10	4
South	50 to 99	85	10	5
North	100 to 249	18	6	2
South	100 to 249	28	8	1
North	250 to 499	10	6	0
South	250 to 499	3	2	0
North	1,000 to 4,999	1	1	1
South	1,000 to 4,999	2	2	0
Total		**10,764**	**125**	**95**

E.4 Expansion Weights

Lighting Contractor Strata Weights

The weighting methodology was developed using revenue data from the electrical contractors in the population and information on the share of electrical contractor revenue derived from the sales or installation of lighting that was collected as part of the Joint Lighting Contractor Telephone Survey. To develop an estimate of the revenue for the population of lighting contractors, the following steps were undertaken:

- By stratum, the electrical contractors' revenues were summed to develop an estimate of revenue for the electrical contractor population in California.
- To develop an estimate of lighting contractor revenue by stratum, for the electrical contractors that participated in the survey it was necessary to determine the share of the electrical contractor revenues that were derived from the sales and installation of lighting measures.
  - Determine if the electrical contractor installed or sold lighting measures. If the contractor did not install or sell lighting measures, attribute none of the contractor's revenue to lighting contractors.
  - If the electrical contractor installed or sold lighting measures, determine the share of their total revenue generated from lighting sales and installations in California.
  - Sum all of the revenues associated with electrical contractors we spoke with as part of the phone survey. These revenues include the electrical contractor revenues for contractors that state that they do not sell or install lighting.
  - Sum all of the revenues associated with lighting sales and installations from the electrical contractors we spoke with as part of the phone surveys.
  - Divide the lighting revenues by the revenue associated with electrical contractors to develop a ratio or share of the electrical contractor revenues that are derived from lighting sales and installations.
  - Multiply the lighting revenue share and the revenue from the population of electrical contractors to develop the revenue for the population of lighting contractors.

Using the information on the revenue for the population of lighting contractors and information on each of the sampled site's lighting revenues, the weight for a given contractor is developed using the following formula:

$$W_{ij} = \frac{Pop\ LT\ Rev_j * LT\ Rev_i}{\sum LT\ Rev_j}$$

Where:

W_{ij} is the weight for lighting contractor i in strata j,

$Pop\ LT\ Rev_j$ is the revenue for the population of lighting contractors in stratum j,

$LT\ Rev_i$ is the lighting revenue for contractor i in stratum j, and

$\sum LT\ Rev_j$ is the lighting revenue for lighting contractors interviewed as part of stratum j.

This methodology weighs up an individual contractor's lighting revenue to our best understanding of their share to the lighting contractors' revenue in California. The final set of weights applied to the survey responses from each stratum are shown in below.

Table 1: Lighting Contractor Strata Weights

Region	Number of Employees	Weight
North	1 to 2	15.85
South	1 to 2	78.12
North	3 to 4	9.88
South	3 to 4	11.21
North	5 to 9	8.66
South	5 to 9	6.11
North	10 to 19	4.71
South	10 to 19	2.82
North	20 to 49	3.96
South	20 to 49	3.94
North	50 to 99	3.27
South	50 to 99	5.00
North	100 to 249	15.85
South	100 to 249	78.12

Appendix F

Ex Ante Measure Cost Estimates Based on READI v.1.0.4 Definitions for In-scope Measures

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F.1 Hedonic Model Estimates

F.2 Simple Average and Built-Up Estimates

F.1 Hedonic Model Estimates

	Measure Information						Total Costs							Per Unit Costs						
Technology	READI Index ID	Match Pair	Description	Measure Type	Sector	Unit	Equipment Cost	Labor Hours	CA Average Labor Rate	Labor Cost	Misc. Costs	Full Installed Cost	Incremental Cost	Equipment Cost per unit	Labor Cost per Unit	Misc. Costs Per Unit	Misc. Fixed Costs per Project	Full Cost per Unit	Incremental Cost per Unit	Incremental Fixed Cost per Project
Appliances and Electronics																				
Refrigerators (full size residential)	6, 10021	Baseline	Refrigerator: Bottom Mount Freezer, Large, 573 rated kWh/yr	RobNc	Res	Unit	$993.50	N/A	N/A	N/A	N/A	$993.50	-							
	6, 10021	Measure	Energy Star(R) Refrigerator: Bottom Mount Freezer without through-the-door ice - large (16.5-25 ft3 TV) - 487 kWh/yr	RobNc	Res	Unit	$1,022.37	N/A	N/A	N/A	N/A	$1,022.37	$28.87							
	7	Baseline	Refrigerator: Bottom Mount Freezer, Small; 518 rated kWh/yr	RobNc	Res	Unit	$817.19	N/A	N/A	N/A	N/A	$817.19	-							
	7	Measure	Energy Star(R) Refrigerator: Bottom Mount Freezer without through-the-door ice - small (8-16.5 ft3 TV) - 447 kWh/yr	RobNc	Res	Unit	$839.00	N/A	N/A	N/A	N/A	$839.00	$21.80							
	8	Baseline	Refrigerator: Side Mount Freezer, Large; 665 rated kWh/yr	ErRobNc	Res	Unit	$550.57	N/A	N/A	N/A	N/A	$550.57	-							
	8	Measure	Energy Star(R) Refrigerator: Side Mount Freezer without through-the-door ice - large (23-31ft3 TV) - 565 kWh/yr	ErRobNc	Res	Unit	$586.03	N/A	N/A	N/A	N/A	$586.03	$35.46							
	9	Baseline	Refrigerator: Side Mount Freezer, Large, Ice Maker; 730 rated kWh/yr	ErRobNc	Res	Unit	$1,041.45	N/A	N/A	N/A	N/A	$1,041.45	-							
	9	Measure	Energy Star(R) Refrigerator: Side Mount Freezer with through-the-door ice - large (23-31 ft3 TV) - 620 kWh/yr	ErRobNc	Res	Unit	$1,081.62	N/A	N/A	N/A	N/A	$1,081.62	$40.17							
	10	Baseline	Refrigerator: 620 rated kWh/yr	ErRobNc	Res	Unit	$381.44	N/A	N/A	N/A	N/A	$381.44	-							
	10	Measure	Energy Star(R) Refrigerator: Side Mount Freezer without through-the-door ice - medium (15-23 ft3 TV) - 528 kWh/yr	ErRobNc	Res	Unit	$413.14	N/A	N/A	N/A	N/A	$413.14	$31.69							
	11	Baseline	Refrigerator: 639 rated kWh/yr	ErRobNc	Res	Unit	$894.00	N/A	N/A	N/A	N/A	$894.00	-							
	11	Measure	Energy Star(R) Refrigerator: Side Mount Freezer with through-the-door ice - medium (15-23 ft3 TV) - 543 kWh/yr	ErRobNc	Res	Unit	$927.57	N/A	N/A	N/A	N/A	$927.57	$33.58							
	12	Baseline	Refrigerator: Top Mount Freezer, Large; 532 rated kWh/yr	ErRobNc	Res	Unit	$663.36	N/A	N/A	N/A	N/A	$663.36	-							
	12	Measure	Energy Star(R) Refrigerator: Top Mount Freezer without through-the-door ice - large (20-25 ft3 TV) - 452 kWh/yr	ErRobNc	Res	Unit	$689.40	N/A	N/A	N/A	N/A	$689.40	$26.04							
	13	Baseline	Refrigerator: Top Mount Freezer, Medium; 469 rated kWh/yr	ErRobNc	Res	Unit	$574.08	N/A	N/A	N/A	N/A	$574.08	-							
	13	Measure	Energy Star(R) Refrigerator: Top Mount Freezer without through-the-door ice - medium (15-20 ft3 TV) - 399 kWh/yr	ErRobNc	Res	Unit	$595.41	N/A	N/A	N/A	N/A	$595.41	$21.33							
	14	Baseline	Refrigerator: Top Mount Freezer, Small; 420 rated kWh/yr	ErRobNc	Res	Unit	$478.21	N/A	N/A	N/A	N/A	$478.21	-							
	14	Measure	Energy Star(R) Refrigerator: Top Mount Freezer without through-the-door ice - small (10-15 ft3 TV) - 357 kWh/yr	ErRobNc	Res	Unit	$496.24	N/A	N/A	N/A	N/A	$496.24	$18.03							
	10023	Baseline	Refrigerator: Bottom Mount Freezer, Large, (16.5-25 ft3 TV) 900 rated kWh/yr	RobNc	Res	Unit	$839.49	N/A	N/A	N/A	N/A	$839.49	-							
	10023	Measure	Refrigerator: Energy Star Bottom Mount Freezer without through-the-door ice , Large, (16.5-25 ft3 TV) 500 rated kWh/yr	RobNc	Res	Unit	$1,016.25	N/A	N/A	N/A	N/A	$1,016.25	$176.76							
	10024	Baseline	Refrigerator: Bottom Mount Freezer, Large, (16.5-25 ft3 TV) 1800 rated kWh/yr	RobNc	Res	Unit	$415.59	N/A	N/A	N/A	N/A	$415.59	-							
	10024	Measure	Refrigerator: Energy Star Bottom Mount Freezer without through-the-door ice , Large, (16.5-25 ft3 TV) 600 rated kWh/yr	RobNc	Res	Unit	$969.15	N/A	N/A	N/A	N/A	$969.15	$553.56							
Clothes Washers (side by side, top loading)	Workpaper measures	Baseline	Top-loading, Title 20 code minimum, MEF=1.26, assumed 3.5 ft3 capacity	RobNc	Res	Unit	$466.37			N/A	N/A	$466.37	-							
		Measure	Top-loading, CEE Tier 1, MEF = 2.0, assumed 3.5 ft3 capacity	RobNc	Res	Unit	$495.17			N/A	N/A	$495.17	$28.79							
		Measure	Top-loading, CEE Tier 2, MEF = 2.2, assumed 3.5 ft3 capacity	RobNc	Res	Unit	$502.95			N/A	N/A	$502.95	$36.57							
		Measure	Top-loading, CEE Tier 3, MEF = 2.4, assumed 3.5 ft3 capacity	RobNc	Res	Unit	$510.73			N/A	N/A	$510.73	$44.36							
		Baseline	Top-loading, Title 20 code minimum, MEF=1.26, assumed 4.0 ft3 capacity	RobNc	Res	Unit	$567.84			N/A	N/A	$567.84	-							
		Measure	Top-loading, CEE Tier 1, MEF = 2.0, assumed 4.0 ft3 capacity	RobNc	Res	Unit	$596.63			N/A	N/A	$596.63	$28.79							
		Measure	Top-loading, CEE Tier 2, MEF = 2.2, assumed 4.0 ft3 capacity	RobNc	Res	Unit	$604.41			N/A	N/A	$604.41	$36.57							
		Measure	Top-loading, CEE Tier 3, MEF = 2.4, assumed 4.0 ft3 capacity	RobNc	Res	Unit	$612.20			N/A	N/A	$612.20	$44.36							
Clothes Washers (stackable, front loading)	Workpaper measures	Baseline	Top-loading, Title 20 code minimum, MEF=1.26, assumed 3.5 ft3 capacity	RobNc	Res	Unit	$466.37			N/A	N/A	$466.37	-							
		Measure	Front-loading, CEE Tier 1, MEF = 2.0, assumed 3.5 ft3 capacity	RobNc	Res	Unit	$676.50			N/A	N/A	$676.50	$210.12							
		Measure	Front-loading, CEE Tier 2, MEF = 2.2, assumed 3.5 ft3 capacity	RobNc	Res	Unit	$682.28			N/A	N/A	$682.28	$215.90							
		Measure	Front-loading, CEE Tier 3, MEF = 2.4, assumed 3.5 ft3 capacity	RobNc	Res	Unit	$688.05			N/A	N/A	$688.05	$221.68							
		Baseline	Top-loading, Title 20 code minimum, MEF=1.26, assumed 4.0 ft3 capacity	RobNc	Res	Unit	$567.84			N/A	N/A	$567.84	-							
		Measure	Front-loading, CEE Tier 1, MEF = 2.0, assumed 4.0 ft3 capacity	RobNc	Res	Unit	$676.50			N/A	N/A	$676.50	$108.66							
		Measure	Front-loading, CEE Tier 2, MEF = 2.2, assumed 4.0 ft3 capacity	RobNc	Res	Unit	$682.28			N/A	N/A	$682.28	$114.44							
		Measure	Front-loading, CEE Tier 3, MEF = 2.4, assumed 4.0 ft3 capacity	RobNc	Res	Unit	$688.05			N/A	N/A	$688.05	$120.22							
LED-backlit LCD Televisions (55" screen size)	Workpaper measure	Baseline	Title 20 code minimum, 177.4 W on-mode power, 1 W sleep mode power, assumed 1270 in2 screen area	Rob	Res	Unit	$1,564.05			N/A	N/A	$1,564.05	-							
		Measure	Energy Star 5.1 + 20%, 86.4 W on-mode power, assumed 1 W sleep mode power, 1270 in2 screen area	Rob	Res	Unit	$1,483.34			N/A	N/A	$1,483.34	-$80.71							
		Measure	Energy Star 5.1 + 35%, 70.2 W on-mode power, assumed 1 W sleep mode power, 1270 in2 screen area	Rob	Res	Unit	$1,468.97			N/A	N/A	$1,468.97	-$95.08							
LED-backlit LCD Televisions (46" screen size)	Workpaper measure	Baseline	Title 20 code minimum, 129.2 W on-mode power, 1 W sleep mode power, assumed 868 in2 screen area	Rob	Res	Unit	$867.12			N/A	N/A	$867.12	-							
		Measure	Energy Star 5.1 + 20%, 72.7 W on-mode power, assumed 1 W sleep mode power, 868 in2 screen area	Rob	Res	Unit	$767.67			N/A	N/A	$767.67	-$99.45							
		Measure	Energy Star 5.1 + 35%, 59.1 W on-mode power, assumed 1 W sleep mode power, 868 in2 screen area	Rob	Res	Unit	$743.73			N/A	N/A	$743.73	-$123.38							

	Measure Information						Total Costs							Per Unit Costs						
Technology	READI Index ID	Match Pair	Description	Measure Type	Sector	Unit	Equipment Cost	Labor Hours	CA Average Labor Rate	Labor Cost	Misc. Costs	Full Installed Cost	Incremental Cost	Equipment Cost per unit	Labor Cost per Unit	Misc. Costs Per Unit	Misc. Fixed Costs per Project	Full Cost per Unit	Incremental Cost per Unit	Incremental Fixed Cost per Project
LED-backlit LCD Televisions (40" screen size)	Workpaper measure	Baseline	Title 20 code minimum, 106.8 W on-mode power, 1 W sleep mode power, assumed 682 in2 screen area	Rob	Res	Unit	$639.05			N/A	N/A	$639.05	-							
		Measure	Energy Star 5.1 + 20%, 60.2 W on-mode power, assumed 1 W sleep mode power, 682 in2 screen area	Rob	Res	Unit	$480.50			N/A	N/A	$480.50	-$158.55							
		Measure	Energy Star 5.1 + 35%, 49 W on-mode power, assumed 1 W sleep mode power, 682 in2 screen area	Rob	Res	Unit	$442.40			N/A	N/A	$442.40	-$196.66							
LED-backlit LCD Televisions (32" screen size)	Workpaper measure	Baseline	Title 20 code minimum, 76 W on-mode power, 1 W sleep mode power, assumed 425 in2 screen area	Rob	Res	Unit	$321.65			N/A	N/A	$321.65	-							
		Measure	Energy Star 5.1 + 20%, 43 W on-mode power, assumed 1 W sleep mode power, 425 in2 screen area	Rob	Res	Unit	$267.25			N/A	N/A	$267.25	-$54.40							
		Measure	Energy Star 5.1 + 35%, 34.9 W on-mode power, assumed 1 W sleep mode power, 425 in2 screen area	Rob	Res	Unit	$253.90			N/A	N/A	$253.90	-$67.75							
LED-backlit LCD Televisions (22" screen size)	Workpaper measure	Baseline	Title 20 code minimum, 48.7 W on-mode power, 1 W sleep mode power, assumed 197.5 in2 screen area	Rob	Res	Unit	$153.11			N/A	N/A	$153.11	-							
		Measure	Energy Star 5.1 + 20%, 24.5 W on-mode power, assumed 1 W sleep mode power, 197.5 in2 screen area	Rob	Res	Unit	$126.54			N/A	N/A	$126.54	-$26.57							
		Measure	Energy Star 5.1 + 35%, 19.9 W on-mode power, assumed 1 W sleep mode power, 425 in2 screen area	Rob	Res	Unit	$121.49			N/A	N/A	$121.49	-$31.62							
LED-backlit LCD Televisions (19" screen size)	Workpaper measure	Baseline	Title 20 code minimum, 42.7 W on-mode power, 1 W sleep mode power, assumed 147 in2 screen area	Rob	Res	Unit	$149.55			N/A	N/A	$149.55	-							
		Measure	Energy Star 5.1 + 20%, 19.3 W on-mode power, assumed 1 W sleep mode power, 147 in2 screen area	Rob	Res	Unit	$125.47			N/A	N/A	$125.47	-$24.08							
		Measure	Energy Star 5.1 + 35%, 15.7 W on-mode power, assumed 1 W sleep mode power, 147 in2 screen area	Rob	Res	Unit	$121.76			N/A	N/A	$121.76	-$27.78							
CCFL-backlit LCD Televisions (55" screen size)	Workpaper measure	Baseline	Title 20 code minimum, 177.4 W on-mode power, 1 W sleep mode power, assumed 1270 in2 screen area	Rob	Res	Unit	$742.27			N/A	N/A	$742.27	-							
		Measure	Energy Star 5.1 + 20%, 86.4 W on-mode power, assumed 1 W sleep mode power, 1270 in2 screen area	Rob	Res	Unit	$849.57			N/A	N/A	$849.57	$107.30							
		Measure	Energy Star 5.1 + 35%, 70.2 W on-mode power, assumed 1 W sleep mode power, 1270 in2 screen area	Rob	Res	Unit	$868.67			N/A	N/A	$868.67	$126.40							
CCFL-backlit LCD Televisions (46" screen size)	Workpaper measure	Baseline	Title 20 code minimum, 129.2 W on-mode power, 1 W sleep mode power, assumed 868 in2 screen area	Rob	Res	Unit	$510.04			N/A	N/A	$510.04	-							
		Measure	Energy Star 5.1 + 20%, 72.7 W on-mode power, assumed 1 W sleep mode power, 868 in2 screen area	Rob	Res	Unit	$524.34			N/A	N/A	$524.34	$14.30							
		Measure	Energy Star 5.1 + 35%, 59.1 W on-mode power, assumed 1 W sleep mode power, 868 in2 screen area	Rob	Res	Unit	$527.78			N/A	N/A	$527.78	$17.74							
CCFL-backlit LCD Televisions (40" screen size)	Workpaper measure	Baseline	Title 20 code minimum, 106.8 W on-mode power, 1 W sleep mode power, assumed 682 in2 screen area	Rob	Res	Unit	$354.00			N/A	N/A	$354.00	-							
		Measure	Energy Star 5.1 + 20%, 60.2 W on-mode power, assumed 1 W sleep mode power, 682 in2 screen area	Rob	Res	Unit	$360.64			N/A	N/A	$360.64	$6.64							
		Measure	Energy Star 5.1 + 35%, 48.9 W on-mode power, assumed 1 W sleep mode power, 682 in2 screen area	Rob	Res	Unit	$362.25			N/A	N/A	$362.25	$8.25							
CCFL-backlit LCD Televisions (32" screen size)	Workpaper measure	Baseline	Title 20 code minimum, 76 W on-mode power, 1 W sleep mode power, assumed 425 in2 screen area	Rob	Res	Unit	$200.89			N/A	N/A	$200.89	-							
		Measure	Energy Star 5.1 + 20%, 43 W on-mode power, assumed 1 W sleep mode power, 425 in2 screen area	Rob	Res	Unit	$156.81			N/A	N/A	$156.81	-$44.08							
		Measure	Energy Star 5.1 + 35%, 34.9 W on-mode power, assumed 1 W sleep mode power, 425 in2 screen area	Rob	Res	Unit	$145.99			N/A	N/A	$145.99	-$54.90							
CCFL-backlit LCD Televisions (22" screen size)	Workpaper measure	Baseline	Title 20 code minimum, 48.7 W on-mode power, 1 W sleep mode power, assumed 197.5 in2 screen area	Rob	Res	Unit	$94.42			N/A	N/A	$94.42	-							
		Measure	Energy Star 5.1 + 20%, 24.5 W on-mode power, assumed 1 W sleep mode power, 197.5 in2 screen area	Rob	Res	Unit	$107.69			N/A	N/A	$107.69	$13.27							
		Measure	Energy Star 5.1 + 35%, 19.9 W on-mode power, assumed 1 W sleep mode power, 425 in2 screen area	Rob	Res	Unit	$110.22			N/A	N/A	$110.22	$15.79							
CCFL-backlit LCD Televisions (19" screen size)	Workpaper measure	Baseline	Title 20 code minimum, 42.7 W on-mode power, 1 W sleep mode power, assumed 147 in2 screen area	Rob	Res	Unit	$183.10			N/A	N/A	$183.10	-							
		Measure	Energy Star 5.1 + 20%, 19.3 W on-mode power, assumed 1 W sleep mode power, 147 in2 screen area	Rob	Res	Unit	$134.06			N/A	N/A	$134.06	-$49.03							
		Measure	Energy Star 5.1 + 35%, 15.7 W on-mode power, assumed 1 W sleep mode power, 147 in2 screen area	Rob	Res	Unit	$126.52			N/A	N/A	$126.52	-$56.58							
Plasma Televisions (all screen sizes)	Workpaper measure	Baseline	Title 20 code minimum, 146.7 W on-mode power, 1 W sleep mode power, assumed 1014 in2 screen area	Rob	Res	Unit	$2,571.15			N/A	N/A	$2,571.15	-							
		Measure	Energy Star 5.1 + 20%, 82.5 W on-mode power, assumed 1 W sleep mode power, 868 in2 screen area	Rob	Res	Unit	$948.95			N/A	N/A	$948.95	-$1,622.20							
		Measure	Energy Star 5.1 + 35%, 67.1 W on-mode power, assumed 1 W sleep mode power, 868 in2 screen area	Rob	Res	Unit	$559.82			N/A	N/A	$559.82	-$2,011.32							

	Measure Information						Total Costs							Per Unit Costs						
Technology	READI Index ID	Match Pair	Description	Measure Type	Sector	Unit	Equipment Cost	Labor Hours	CA Average Labor Rate	Labor Cost	Misc. Costs	Full Installed Cost	Incremental Cost	Equipment Cost per unit	Labor Cost per Unit	Misc. Costs Per Unit	Misc. Fixed Costs per Project	Full Cost per Unit	Incremental Cost per Unit	Incremental Fixed Cost per Project
Residential HVAC																				
Room AC (cooling only, window units only)	Workpaper measures	Baseline	Non-Energy Star with louvered sides 6,000 btuh 9.7 EER	RobNc	Res	Unit	$147.06			N/A	N/A	$147.06	-							
		Measure	Energy Star with louvered sides 6,000 btuh 10.7 EER	RobNc	Res	Unit	$164.35			N/A	N/A	$164.35	$17.29							
		Baseline	Non-Energy Star without louvered sides 6,000 btuh 9.0 EER	RobNc	Res	Unit	$127.78			N/A	N/A	$127.78	-							
		Measure	Energy Star without louvered sides 6,000 btuh 9.9 EER	RobNc	Res	Unit	$142.32			N/A	N/A	$142.32	$14.54							
		Baseline	Non-Energy Star with louvered sides 8,000 btuh 9.8 EER	RobNc	Res	Unit	$195.82			N/A	N/A	$195.82	-							
		Measure	Energy Star with louvered sides 8,000 btuh 10.8 EER	RobNc	Res	Unit	$213.11			N/A	N/A	$213.11	$17.29							
		Baseline	Non-Energy Star with louvered sides 14,000 btuh 9.7 EER	RobNc	Res	Unit	$331.06			N/A	N/A	$331.06	-							
		Measure	Energy Star with louvered sides 14,000 btuh 10.7 EER	RobNc	Res	Unit	$348.35			N/A	N/A	$348.35	$17.29							
		Baseline	Non-Energy Star with louvered sides 20,000 btuh 8.5 EER	RobNc	Res	Unit	$436.01			N/A	N/A	$436.01	-							
		Measure	Energy Star with louvered sides 20,000 btuh 9.4 EER	RobNc	Res	Unit	$450.55			N/A	N/A	$450.55	$14.54							
Gas Furnaces (residential)	145 - 154, 10103 - 10107	Baseline	Furnace AFUE 80 assumed 60,000 BtuH w/o variable speed fan	ErRobNc	Res	MBH	$640.51	4.26	$68.34	$291.13	$0.00	$931.64	-	$10.68	$4.85	0	0	$15.53	-	-
	145, 10103	Measure	Efficient Residential Gas Furnace - AFUE 81 assumed 60,000 BtuH w/o variable speed fan	ErRobNc	Res	MBH	$667.65	4.26	$68.34	$291.13	$0.00	$958.78	$27.14	$11.13	$4.85	0	0	$15.98	$0.45	0
	146, 10104	Measure	Efficient Residential Gas Furnace - AFUE 90 assumed 60,000 BtuH w/o variable speed fan	ErRobNc	Res	MBH	$911.91	4.26	$68.34	$291.13	$0.00	$1,203.04	$271.40	$15.20	$4.85	0	0	$20.05	$4.52	0
	147	Measure	Efficient Residential Gas Furnace - AFUE 91 assumed 60,000 BtuH w/o variable speed fan	ErRobNc	Res	MBH	$939.05	4.26	$68.34	$291.13	$0.00	$1,230.18	$298.54	$15.65	$4.85	0	0	$20.50	$4.98	0
	148, 10105	Measure	Efficient Residential Gas Furnace - AFUE 92 assumed 60,000 BtuH with variable speed fan	ErRobNc	Res	MBH	$1,086.18	4.26	$68.34	$291.13	$0.00	$1,377.30	$445.67	$18.10	$4.85	0	0	$22.96	$7.43	0
	149	Measure	Efficient Residential Gas Furnace - AFUE 93 assumed 60,000 BtuH with variable speed fan	ErRobNc	Res	MBH	$1,113.32	4.26	$68.34	$291.13	$0.00	$1,404.44	$472.81	$18.56	$4.85	0	0	$23.41	$7.88	0
	150, 10106	Measure	Efficient Residential Gas Furnace - AFUE 94 assumed 60,000 BtuH with variable speed fan	ErRobNc	Res	MBH	$1,140.46	4.26	$68.34	$291.13	$0.00	$1,431.58	$499.95	$19.01	$4.85	0	0	$23.86	$8.33	0
	151	Measure	Efficient Residential Gas Furnace - AFUE 95 assumed 60,000 BtuH with variable speed fan	ErRobNc	Res	MBH	$1,167.60	4.26	$68.34	$291.13	$0.00	$1,458.72	$527.09	$19.46	$4.85	0	0	$24.31	$8.78	0
	152, 10107	Measure	Efficient Residential Gas Furnace - AFUE 96 assumed 60,000 BtuH w/o variable speed fan	ErRobNc	Res	MBH	$1,074.75	4.26	$68.34	$291.13	$0.00	$1,365.88	$434.24	$17.91	$4.85	0	0	$22.76	$7.24	0
	153	Measure	Efficient Residential Gas Furnace - AFUE 97 assumed 60,000 BtuH with variable speed fan	ErRobNc	Res	MBH	$1,221.88	4.26	$68.34	$291.13	$0.00	$1,513.01	$581.37	$20.36	$4.85	0	0	$25.22	$9.69	0
	154	Measure	Efficient Residential Gas Furnace - AFUE 98 assumed 60,000 BtuH with variable speed fan	ErRobNc	Res	MBH	$1,249.02	4.26	$68.34	$291.13	$0.00	$1,540.15	$608.51	$20.82	$4.85	0	0	$25.67	$10.14	0
	145 - 154, 10103 - 10107	Baseline	Furnace AFUE 80 assumed 150,000 BtuH w/o variable speed fan	ErRobNc	Res	MBH	$1,026.26	5.79	$68.34	$395.69	$0.00	$1,421.95	-	$6.84	$2.64	0	0	$9.48	-	-
	145, 10103	Measure	Efficient Residential Gas Furnace - AFUE 81 assumed 150,000 BtuH w/o variable speed fan	ErRobNc	Res	MBH	$1,053.40	5.79	$68.34	$395.69	$0.00	$1,449.09	$27.14	$7.02	$2.64	0	0	$9.66	$0.18	0
	146, 10104	Measure	Efficient Residential Gas Furnace - AFUE 90 assumed 150,000 BtuH w/o variable speed fan	ErRobNc	Res	MBH	$1,297.66	5.79	$68.34	$395.69	$0.00	$1,693.35	$271.40	$8.65	$2.64	0	0	$11.29	$1.81	0
	147	Measure	Efficient Residential Gas Furnace - AFUE 91 assumed 150,000 BtuH w/o variable speed fan	ErRobNc	Res	MBH	$1,324.80	5.79	$68.34	$395.69	$0.00	$1,720.49	$298.54	$8.83	$2.64	0	0	$11.47	$1.99	0
	148, 10105	Measure	Efficient Residential Gas Furnace - AFUE 92 assumed 150,000 BtuH with variable speed fan	ErRobNc	Res	MBH	$1,471.92	5.79	$68.34	$395.69	$0.00	$1,867.61	$445.67	$9.81	$2.64	0	0	$12.45	$2.97	0
	149	Measure	Efficient Residential Gas Furnace - AFUE 93 assumed 150,000 BtuH with variable speed fan	ErRobNc	Res	MBH	$1,499.06	5.79	$68.34	$395.69	$0.00	$1,894.75	$472.81	$9.99	$2.64	0	0	$12.63	$3.15	0
	150, 10106	Measure	Efficient Residential Gas Furnace - AFUE 94 assumed 150,000 BtuH w/o variable speed fan	ErRobNc	Res	MBH	$1,406.22	5.79	$68.34	$395.69	$0.00	$1,801.91	$379.96	$9.37	$2.64	0	0	$12.01	$2.53	0
	151	Measure	Efficient Residential Gas Furnace - AFUE 95 assumed 150,000 BtuH with variable speed fan	ErRobNc	Res	MBH	$1,553.34	5.79	$68.34	$395.69	$0.00	$1,949.03	$527.09	$10.36	$2.64	0	0	$12.99	$3.51	0
	152, 10107	Measure	Efficient Residential Gas Furnace - AFUE 96 assumed 150,000 BtuH with variable speed fan	ErRobNc	Res	MBH	$1,580.48	5.79	$68.34	$395.69	$0.00	$1,976.17	$554.23	$10.54	$2.64	0	0	$13.17	$3.69	0
	153	Measure	Efficient Residential Gas Furnace - AFUE 97 assumed 150,000 BtuH with variable speed fan	ErRobNc	Res	MBH	$1,607.62	5.79	$68.34	$395.69	$0.00	$2,003.31	$581.37	$10.72	$2.64	0	0	$13.36	$3.88	0
	154	Measure	Efficient Residential Gas Furnace - AFUE 98 assumed 150,000 BtuH with variable speed fan	ErRobNc	Res	MBH	$1,634.76	5.79	$68.34	$395.69	$0.00	$2,030.45	$608.51	$10.90	$2.64	0	0	$13.54	$4.06	0
	9053	Baseline	AFUE 78 furnace assumed 150,000 BtuH w/o variable speed fan	RobNc	Com	MBH	$971.98	5.79	$68.34	$395.69	$0.00	$1,367.67	-	$6.48	$2.64	0	0	$9.12	-	-
	9053	Measure	Efficient Gas Furnace - AFUE 94 assumed 150,000 BtuH w/o variable speed fan	RobNc	Com	MBH	$1,406.22	5.79	$68.34	$395.69	$0.00	$1,801.91	$434.24	$9.37	$2.64	$0.00	$0.00	$12.01	$2.89	$0.00

	Measure Information						Total Costs							Per Unit Costs							
Technology	READI Index ID	Match Pair	Description	Measure Type	Sector	Unit	Equipment Cost	Labor Hours	CA Average Labor Rate	Labor Cost	Misc. Costs	Full Installed Cost	Incremental Cost	Equipment Cost per unit	Labor Cost per Unit	Misc. Costs Per Unit	Misc. Fixed Costs per Project	Full Cost per Unit	Incremental Cost per Unit	Incremental Fixed Cost per Project
Split-System HP (residential and commerical)	61 - 64	Baseline	Split HP SEER = 13 assumed 36,000 BtuH	ErRobNc	Com	MBH	$1,784.62	31.35	$90.90	$2,850.15	$3,045.48	$7,680.25	-							
	61	Measure	Split HP SEER = 14.0 (< 55 kBTUh) - Combined SEER 13 and SEER 14.5 hp assumed 36,000 BtuH	ErRobNc	Com	MBH	$2,332.91	31.35	$90.90	$2,850.15	$3,045.48	$8,228.54	$548.29							
	62	Measure	Split HP SEER = 13.0 (< 55 kBTUh), EER = 11.07, HSPF = 7.70, COP = 3.28; no Econo; 1-spd Fan assumed 36,000 BtuH	ErRobNc	Com	MBH	$1,784.62	31.35	$90.90	$2,850.15	$3,045.48	$7,680.25	$0.00							
	63	Measure	Split HP SEER = 14.0 (< 55 kBTUh), EER = 12.00, HSPF = 8.50, COP = 3.74; no Econo; 1-spd Fan assumed 36,000 BtuH	ErRobNc	Com	MBH	$2,332.91	31.35	$90.90	$2,850.15	$3,045.48	$8,228.54	$548.29							
	64	Measure	Split HP SEER = 15.0 (< 55 kBTUh), EER = 12.5, HSPF = 9.00, COP = 3.96; no Econo; 1-spd Fan assumed 36,000 BtuH	ErRobNc	Com	MBH	$2,881.20	31.35	$90.90	$2,850.15	$3,045.48	$8,776.83	$1,096.58							
	65, 68, 70, 71, 72	Baseline	Split HP SEER = 13 assumed 59,000 BtuH	ErRobNc	Com	MBH	$2,924.19	31.35	$90.90	$2,850.15	$3,045.48	$8,819.82	-							
	65	Measure	Split HP SEER = 14.0 (55-64 kBTUh) - Combined SEER 13 and SEER 14.5 hp assumed 59,000 BtuH	ErRobNc	Com	MBH	$3,472.48	31.35	$90.90	$2,850.15	$3,045.48	$9,368.11	$548.29							
	68	Measure	Split HP SEER = 15.0 (55-64 kBTUh), EER = 12.5, HSPF = 9.00, COP = 3.96; w/Econo; 2-spd Fan assumed 59,000 BtuH	ErRobNc	Com	MBH	$4,020.77	31.35	$90.90	$2,850.15	$3,045.48	$9,916.40	$1,096.58							
	69	Measure	Split HP SEER = 13.0 (< 65 kbtuh), EER = 11.07, HSPF = 7.70, COP = 3.28 assumed 59,000 BtuH - same as baseline	ErRobNc	Com	MBH	$2,924.19	31.35	$90.90	$2,850.15	$3,045.48	$8,819.82	$0.00							
	70	Measure	Split HP SEER = 14.0 (< 65 kBtuh) - Combined SEER 13 and SEER 14.5 hp assumed 59,000 BtuH	ErRobNc	Com	MBH	$3,472.48	31.35	$90.90	$2,850.15	$3,045.48	$9,368.11	$548.29							
	71	Measure	Split HP SEER = 14.5 (< 65 kbtuh), EER = 12.00, HSPF = 8.50, COP = 3.74 assumed 59,000 BtuH	ErRobNc	Com	MBH	$3,746.63	31.35	$90.90	$2,850.15	$3,045.48	$9,642.26	$822.44							
	72	Measure	Split HP SEER = 15.0 (< 65 kBtuh), EER = 12.5, HSPF = 9.00, COP = 3.96 assumed 59,000 BtuH	ErRobNc	Com	MBH	$4,020.77	31.35	$90.90	$2,850.15	$3,045.48	$9,916.40	$1,096.58							
	74, 75, 76	Baseline	13 SEER Heat Pump assumed 24,000 BtuH	ErRobNc	Res	MBH	$1,190.06	8.00	$90.90	$727.62	$0.00	$1,917.67	-							
	73	Measure	13 SEER Heat Pump (HSPF = 8.1) assumed 24,000 BtuH - same as baseline	ErRobNc	Res	MBH	$1,190.06	8.00	$90.90	$727.62	$0.00	$1,917.67	$0.00							
	74	Measure	14 SEER Heat Pump (HSPF = 8.6) assumed 24,000 BtuH	ErRobNc	Res	MBH	$1,738.35	8.00	$90.90	$727.62	$0.00	$2,465.96	$548.29							
	75	Measure	15 SEER Heat Pump (HSPF = 8.8) assumed 24,000 BtuH	ErRobNc	Res	MBH	$2,286.64	8.00	$90.90	$727.62	$0.00	$3,014.25	$1,096.58							
	76	Measure	16 SEER Heat Pump (HSPF = 8.4) assumed 24,000 BtuH	ErRobNc	Res	MBH	$2,834.93	8.00	$90.90	$727.62	$0.00	$3,562.54	$1,644.87							

	Measure Information						Total Costs							Per Unit Costs						
Technology	READI Index ID	Match Pair	Description	Measure Type	Sector	Unit	Equipment Cost	Labor Hours	CA Average Labor Rate	Labor Cost	Misc. Costs	Full Installed Cost	Incremental Cost	Equipment Cost per unit	Labor Cost per Unit	Misc. Costs Per Unit	Misc. Fixed Costs per Project	Full Cost per Unit	Incremental Cost per Unit	Incremental Fixed Cost per Project
Split-System DX (residential and commerical)	125	Baseline	Split AC SEER = 13.0 (< 55 kBtuh), EER = 11.06, Clg EIR = 0.2557, Supply Fan W/cfm = 0.379; no Econo; 1-spd Fan assumed 24,000 BtuH	ErRul	Com	MBH	$937.34	31.35	$91.34	$2,863.98	$3,700.19	$7,501.51	-							
	124	Measure	Split AC SEER = 13.0 (< 55 kBTUh), EER = 11.06, Clg EIR = 0.2557, Supply Fan W/cfm = 0.379; no Econo; 1-spd Fan assumed 24,000 BtuH - same as baseline	ErRul	Com	MBH	$937.34	31.35	$91.34	$2,863.98	$3,700.19	$7,501.51	$0.00							
	125	Measure	Split AC SEER = 14.0 (< 55 kBTUh), EER = 12.04, Clg EIR = 0.2456, Supply Fan W/cfm = 0.306; no Econo; 1-spd Fan assumed 24,000 BtuH	ErRul	Com	MBH	$1,213.72	31.35	$91.34	$2,863.98	$3,700.19	$7,777.89	$276.38							
	127, 130	Baseline	Split AC SEER = 13.00; EER = 11.06; Clg EIR = 0.256; Supply Fan W/cfm = 0.379; no econo assumed 54,000 BtuH	ErRobNc	Com	MBH	$1,765.37	31.35	$91.34	$2,863.98	$3,700.19	$8,329.55	-							
	126	Measure	Split AC SEER = 13.0 (< 65 kBtuh), EER = 11.06, Clg EIR = 0.2557, Supply Fan W/cfm = 0.379 assumed 54,000 BtuH - same as baseline	ErRul	Com	MBH	$1,765.37	31.35	$91.34	$2,863.98	$3,700.19	$8,329.55	$0.00							
	127	Measure	Split AC SEER = 14.0 (< 65 kBtuh), EER = 12.04, Clg EIR = 0.2456, Supply Fan W/cfm = 0.306 assumed 54,000 BtuH	ErRobNc	Com	MBH	$2,041.75	31.35	$91.34	$2,863.98	$3,700.19	$8,605.93	$276.38							
	128	Measure	Split AC SEER = 12.0 (< 65 kBtuh, 3ph), EER = 10.21, Clg EIR = 0.2761, Supply Fan W/cfm = 0.409 assumed 54,000 BtuH - less than baseline	ErRul	Com	MBH	$1,488.99	31.35	$91.34	$2,863.98	$3,700.19	$8,053.17	-$276.38							
	129	Measure	Split AC SEER = 13.0 (< 65 kBtuh, 3ph), EER = 11.06, Clg EIR = 0.2557, Supply Fan W/cfm = 0.379 assumed 54,000 BtuH - same as baseline	ErRul	Com	MBH	$1,765.37	31.35	$91.34	$2,863.98	$3,700.19	$8,329.55	$0.00							
	130	Measure	Split AC SEER = 14.0 (< 65 kBtuh, 3ph), EER = 12.04, Clg EIR = 0.2456, Supply Fan W/cfm = 0.306 assumed 54,000 BtuH	ErRobNc	Com	MBH	$2,041.75	31.35	$91.34	$2,863.98	$3,700.19	$8,605.93	$276.38							
	131	Baseline	13 SEER (11.09 EER) Split System Air Conditioner assumed 48,000 BtuH	ErRul	Res	MBH	$1,599.77	7.26	$91.34	$662.77	$0.00	$2,262.53	-							
	131	Measure	13 SEER (11.09 EER) Split System Air Conditioner assumed 48,000 - same as baseline	ErRul	Res	MBH	$1,599.77	7.26	$91.34	$662.77	$0.00	$2,262.53	$0.00							
	132	Baseline	Split AC SEER = 13.0 (55-64 kBtuh), EER = 11.06, Clg EIR = 0.2557, Supply Fan W/cfm = 0.379; no Econo; 2-spd Fan assumed 60,000 BtuH	ErRul	Com	MBH	$1,930.98	31.35	$91.34	$2,863.98	$3,700.19	$8,495.16	-							
	132	Measure	Split AC SEER = 13.0 (55-64 kBTUh), EER = 11.06, Clg EIR = 0.2557, Supply Fan W/cfm = 0.379; no Econo; 2-spd Fan assumed 60,000 BtuH - same as baseline	ErRul	Com	MBH	$1,930.98	31.35	$91.34	$2,863.98	$3,700.19	$8,495.16	$0.00							
	133	Baseline	Split AC SEER = 14.0 (55-64 kBtuh), EER = 12.04, Clg EIR = 0.2456, Supply Fan W/cfm = 0.306; no Econo; 2-spd Fan assumed 60,000Btuh	ErRobNc	Com	MBH	$2,207.36	31.35	$91.34	$2,863.98	$3,700.19	$8,771.54	-							
	133	Measure	Split AC SEER = 14.0 (55-64 kBTUh), EER = 12.04, Clg EIR = 0.2456, Supply Fan W/cfm = 0.306; no Econo; 2-spd Fan assumed 60,000Btuh - same as baseline	ErRobNc	Com	MBH	$2,207.36	31.35	$91.34	$2,863.98	$3,700.19	$8,771.54	$0.00							
	134 - 141	Baseline	13 SEER (11.09 EER) Split System Air Conditioner assumed 36,000 BtuH	ErRobNc	Res	MBH	$1,268.55	7.26	$91.34	$662.77	$0.00	$1,931.32	-							
	134	Measure	14 SEER (12.15 EER) Split-System Air Conditioner assumed 36,000 BtuH	ErRobNc	Res	MBH	$1,544.93	7.26	$91.34	$662.77	$0.00	$2,207.70	$276.38							
	135	Measure	15 SEER (12.72 EER) Split-System Air Conditioner assumed 36,000 BtuH	ErRobNc	Res	MBH	$1,821.31	7.26	$91.34	$662.77	$0.00	$2,484.08	$552.76							
	136	Measure	16 SEER (11.61 EER) Split-System Air Conditioner assumed 36,000 BtuH	ErRobNc	Res	MBH	$2,097.69	7.26	$91.34	$662.77	$0.00	$2,760.46	$829.14							
	137	Measure	17 SEER (12.28 EER) Split-System Air Conditioner assumed 36,000 BtuH	ErRobNc	Res	MBH	$2,374.07	7.26	$91.34	$662.77	$0.00	$3,036.84	$1,105.52							
	138	Measure	18 SEER (13.37 EER) Split-System Air Conditioner assumed 36,000 BtuH	ErRobNc	Res	MBH	$2,650.45	7.26	$91.34	$662.77	$0.00	$3,313.22	$1,381.90							
	139	Measure	19 SEER (13.82 EER) Split-System Air Conditioner assumed 36,000 BtuH	ErRobNc	Res	MBH	$2,926.83	7.26	$91.34	$662.77	$0.00	$3,589.60	$1,658.28							
	140	Measure	20 SEER (14.43 EER) Split-System Air Conditioner assumed 36,000 BtuH	ErRobNc	Res	MBH	$3,203.21	7.26	$91.34	$662.77	$0.00	$3,865.98	$1,934.66							
	141	Measure	21 SEER (15.03 EER) Split-System Air Conditioner assumed 36,000 BtuH	ErRobNc	Res	MBH	$3,479.59	7.26	$91.34	$662.77	$0.00	$4,142.36	$2,211.04							
Residential HVAC Fan Motors	Workpaper measure	Baseline	0.5 HP Permanent Split Capacitor Motor	Rob	Res	HP	$261.74	2.59	$66.77	$173.18		$434.91	-							
		Measure	0.5 HP Brushless Fan Motor	Rob	Res	HP	$352.42	2.59	$66.77	$173.18		$525.60	$90.68							
Whole House Fans	9114	Baseline	Absense of whole house fan	ROB	Res	Unit	0	0.00	0	0	$0.00	0	-							
	9114	Measure	Whole House Fans assumed 2500 CFM, 1 fan, industrial grade	ROB	Res	Unit	$1,251.73	6.00	$67.02	$402.09	$0.00	$1,653.82	$1,653.82							
	9114	Measure	Whole houe fan assumed 1600 CFM, 1 fan	ROB	Res	Unit	$535.10	6.00	$67.02	$402.09	$0.00	$937.20	$937.20							
	9114	Measure	Whole houe fan assumed 2500 CFM, 1 fan	ROB	Res	Unit	$649.58	6.00	$67.02	$402.09	$0.00	$1,051.68	$1,051.68							
	9114	Measure	Whole houe fan assumed 4500 CFM, 1 fan	ROB	Res	Unit	$903.98	6.00	$67.02	$402.09	$0.00	$1,306.08	$1,306.08							
	9114	Measure	Whole houe fan assumed 1150 CFM, 2 fans	ROB	Res	Unit	$620.20	6.00	$67.02	$402.09	$0.00	$1,022.29	$1,022.29							

	Measure Information						Total Costs							Per Unit Costs						
Technology	READI Index ID	Match Pair	Description	Measure Type	Sector	Unit	Equipment Cost	Labor Hours	CA Average Labor Rate	Labor Cost	Misc. Costs	Full Installed Cost	Incremental Cost	Equipment Cost per unit	Labor Cost per Unit	Misc. Costs Per Unit	Misc. Fixed Costs per Project	Full Cost per Unit	Incremental Cost per Unit	Incremental Fixed Cost per Project
Non-Residential HVAC																				
Fan VFDs (>10hp)	9041	Baseline	T24 minimum: VAV w/30% min-cfm-ratio & w/VSD fans	ErRul	Com	HP	$0.00	0.00	$67.90	$0.00		$0.00	-	$0.00	$0.00			$0.00	-	
	9041	Measure	VFD Supply Fan Motors (assumed 20hp, nema 12 enclosure,no bypass)	ErRul	Com	HP	$2,087.89	19.04	$69.93	$1,331.11		$3,419.00	$3,419.00	$104.39	$66.56			$170.95	$170.95	
	9041	Measure	VFD Supply Fan Motors (assumed 30hp, nema 1 enclosure,no bypass)	ErRul	Com	HP	$2,055.47	22.44	$69.93	$1,569.22		$3,624.68	$3,624.68	$68.52	$52.31			$120.82	$120.82	
	9041	Measure	VFD Supply Fan Motors (assumed 40hp, nema 3 enclosure, with bypass)	ErRul	Com	HP	$4,666.29	25.85	$69.93	$1,807.33		$6,473.62	$6,473.62	$116.66	$45.18			$161.84	$161.84	
	9041	Measure	VFD Supply Fan Motors (assumed 60hp, nema 12 enclosure, no bypass)	ErRul	Com	HP	$4,287.25	35.28	$78.38	$2,764.83		$7,052.08	$7,052.08	$71.45	$46.08			$117.53	$117.53	
	9041	Measure	VFD Supply Fan Motors (assumed 75hp, nema 12 enclosure,no bypass)	ErRul	Com	HP	$5,112.01	36.47	$78.38	$2,858.41		$7,970.42	$7,970.42	$68.16	$38.11			$106.27	$106.27	
	9041	Measure	VFD Supply Fan Motors (assumed 100hp, nema 1 enclosure,no bypass)	ErRul	Com	HP	$5,904.35	38.46	$78.38	$3,014.38		$8,918.73	$8,918.73	$59.04	$30.14			$89.19	$89.19	
	9041	Measure	VFD Supply Fan Motors (assumed 50hp, nema 1 enclosure,no bypass)	ErRul	Com	HP	$3,155.15	29.25	$69.93	$2,045.44		$5,200.58	$5,200.58	$63.10	$40.91			$104.01	$104.01	
Fan VFDs (<= 10hp)	9041	Baseline	T24 minimum: VAV w/30% min-cfm-ratio & w/VSD fans	ErRul	Com	HP	$0.00	0.00	$69.93	$0.00		$0.00	-	$0.00	$0.00			$0.00	-	
	9041	Measure	VFD Supply Fan Motors (assumed 1.5hp, nema 12 enclosure,no bypass)	ErRul	Com	HP	$827.71	9.35	$69.93	$653.67		$1,481.38	$1,481.38	$551.81	$435.78			$987.58	$987.58	
	9041	Measure	VFD Supply Fan Motors (assumed 5hp, nema 1 enclosure,no bypass)	ErRul	Com	HP	$730.88	10.51	$69.93	$735.12		$1,466.00	$1,466.00	$146.18	$147.02			$293.20	$293.20	
	9041	Measure	VFD Supply Fan Motors (assumed 10hp, nema 1 enclosure, no bypass)	ErRul	Com	HP	$1,018.70	12.18	$69.93	$851.48		$1,870.18	$1,870.18	$101.87	$85.15			$187.02	$187.02	
	9041	Measure	VFD Supply Fan Motors (assumed 10hp, nema 3r enclosure,no bypass)	ErRul	Com	HP	$2,243.12	12.18	$69.93	$851.48		$3,094.60	$3,094.60	$224.31	$85.15			$309.46	$309.46	
Demand Control Ventilation	Example Measures	Basline	No DCV	AddOn	Com	Sensor	$0.00	0.00	$0.00	$0.00	$0.00	$0.00	-							
		Measure	Duct Mounted unit single zone	AddOn	Com	Sensor	$529.05	7.50	$86.93	$651.98	$1,192.13	$2,373.16	$2,373.16							
		Measure	Duct Mounted unit with Digital Display and VOC Sensor single zone	AddOn	Com	Sensor	$529.05	7.50	$86.93	$651.98	$1,192.13	$2,373.16	$2,373.16							
		Measure	Duct Mounted unit with Humidity Sensor single zone	AddOn	Com	Sensor	$597.23	7.50	$86.93	$651.98	$1,192.13	$2,441.34	$2,441.34							
		Measure	Duct Mounted unit with Temperature Sensor single zone	AddOn	Com	Sensor	$490.11	7.50	$86.93	$651.98	$1,192.13	$2,334.22	$2,334.22							
		Measure	Wall Mounted unit single zone	AddOn	Com	Sensor	$356.35	7.50	$86.93	$651.98	$1,192.13	$2,200.46	$2,200.46							
		Measure	Wall Mounted unit with Digital Display single zone	AddOn	Com	Sensor	$440.08	7.50	$86.93	$651.98	$1,192.13	$2,284.19	$2,284.19							
		Measure	Wall Mounted unit with Humidity Sensor single zone	AddOn	Com	Sensor	$522.16	7.50	$86.93	$651.98	$1,192.13	$2,366.27	$2,366.27							
		Measure	Wall Mounted unit with Temperature Sensor single zone	AddOn	Com	Sensor	$415.04	7.50	$86.93	$651.98	$1,192.13	$2,259.15	$2,259.15							
		Measure	Wall Mounted unit with Temperature Sensor and Digital Display single zone	AddOn	Com	Sensor	$498.77	7.50	$86.93	$651.98	$1,192.13	$2,342.88	$2,342.88							
		Measure	Wall Mounted unit with Temperature Sensor and Humidity Sensor single zone	AddOn	Com	Sensor	$580.85	7.50	$86.93	$651.98	$1,192.13	$2,424.96	$2,424.96							
		Measure	Wall Mounted unit with Temperature Sensor, Digital Display, and Humidity Sensor single zone	AddOn	Com	Sensor	$664.59	7.50	$86.93	$651.98	$1,192.13	$2,508.70	$2,508.70							

	Measure Information						Total Costs							Per Unit Costs						
Technology	READI Index ID	Match Pair	Description	Measure Type	Sector	Unit	Equipment Cost	Labor Hours	CA Average Labor Rate	Labor Cost	Misc. Costs	Full Installed Cost	Incremental Cost	Equipment Cost per unit	Labor Cost per Unit	Misc. Costs Per Unit	Misc. Fixed Costs per Project	Full Cost per Unit	Incremental Cost per Unit	Incremental Fixed Cost per Project
Direct Evaporative Coolers (non-residential)	9102	Baseline	No evaporative cooler	ErRobNc	Res	ton	$0.00	0.00	$0.00	$0.00	$0.00	$0.00	-	$0.00	$0.00	$0.00	$0.00	$0.00	-	$0.00
	9102	Measure	Direct Evaporative Cooler assumed 3,510 CFM, 0.87 media saturation effectiveness (~3 ton equivalent)	ErRobNc	Res	ton	$1,440.24	4.21	$67.79	$285.46	$0.00	$1,725.70	$1,725.70	$480.08	$95.15	$0.00	$0.00	$575.23	$575.23	$0.00
Indirect Evaporative Coolers	9042, 9043	Baseline	No evaporative cooling (T24 HVAC matches prototype characteristics)	RobNc	Com	tons	$0.00	0.00	$0.00	$0.00	$0.00	$0.00	-	$0.00	$0.00			$0.00	-	
	9042	Measure	Evap Cool Indirect - Central System 65% effectiveness assumed 3,000 cfm, no gas heat	RobNc	Com	tons	$11,201.38	10.06	$79.74	$802.33	$199.61	$12,203.32	$12,203.32	$4,368.54	$312.91	$93.42		$4,774.86	$4,774.86	
	9043	Measure	Evap Cool Indirect - Packaged Sys 65% effectiveness assumed 45,000 cfm, no gas heat	RobNc	Com	tons	$127,465.53	150.93	$79.74	$12,034.92	$2,994.16	$142,494.60	$142,494.60	$3,314.10	$312.91	$93.42		$3,720.43	$3,720.43	
	9103	Baseline	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner assumed 36,000 BtuH	ErRobNc	Res	tons	$1,268.55	7.26	$91.34	$662.77	$0.00	$1,931.32	-	$0.00	$0.00	$0.00	$0.00	$0.00	-	
	9103	Measure	Indirect Evaporative Cooler assumed 3,510 cfm, no gas heat	ErRobNc	Res	tons	$12,613.16	11.77	$79.74	$938.72	$233.54	$13,785.43	$11,854.11	$4,204.39	$312.91	$93.42		$4,610.71	$4,610.71	
Small Packaged DX (<= 5 tons)	115 - 121	Baseline	Pkg AC SEER = 13.0 (< 55 kBtuh), EER = 11.06, Clg EIR = 0.2557, Supply Fan W/cfm = 0.379; no Econo; 1-spd Fan assumed 3 ton	ErRul/ErRobNc	Com	tons	$3,038.37	29.66	$90.13	$2,673.63	$1,763.99	$7,476.00	-	$1,012.79	$891.21	$333.69	$762.93	$2,237.69	-	-
	115	Measure	Pkg AC SEER = 13.0 (< 55 kBTUh), EER = 11.06, Clg EIR = 0.2557, Supply Fan W/cfm = 0.379; no Econo; 1-spd Fan assumed 3 ton	ErRul	Com	tons	$3,038.37	29.66	$90.13	$2,673.63	$1,763.99	$7,476.00	$0.00	$1,012.79	$891.21	$333.69	$762.93	$2,237.69	$0.00	$0.00
	116	Measure	Pkg AC SEER = 14.0 (< 55 kBTUh), EER = 12.04, Clg EIR = 0.2456, Supply Fan W/cfm = 0.306; no Econo; 1-spd Fan assumed 3 ton	ErRul	Com	tons	$3,400.14	29.66	$90.13	$2,673.63	$1,763.99	$7,837.76	$361.77	$1,133.38	$891.21	$333.69	$762.93	$2,358.28	$120.59	$0.00
	117	Measure	Pkg AC SEER = 13.0 (< 65 kBtuh), EER = 11.06, Clg EIR = 0.2557, Supply Fan W/cfm = 0.379 assumed 3 ton	ErRul	Com	tons	$3,038.37	29.66	$90.13	$2,673.63	$1,763.99	$7,476.00	$0.00	$1,012.79	$891.21	$333.69	$762.93	$2,237.69	$0.00	$0.00
	118	Measure	Pkg AC SEER = 14.0 (< 65 kBtuh), EER = 12.04, Clg EIR = 0.2456, Supply Fan W/cfm = 0.306 assumed 3 ton	ErRobNc	Com	tons	$3,400.14	29.66	$90.13	$2,673.63	$1,763.99	$7,837.76	$361.77	$1,133.38	$891.21	$333.69	$762.93	$2,358.28	$120.59	$0.00
	119	Measure	Pkg AC SEER = 12.0 (< 65 kBtuh, 3ph), EER = 10.21, Clg EIR = 0.2761, Supply Fan W/cfm = 0.409 assumed 3 ton	ErRul	Com	tons	$2,676.61	29.66	$90.13	$2,673.63	$1,763.99	$7,114.23	-$361.77	$892.20	$891.21	$333.69	$762.93	$2,117.10	-$120.59	$0.00
	120	Measure	Pkg AC SEER = 13.0 (< 65 kBtuh, 3ph), EER = 11.06, Clg EIR = 0.2557, Supply Fan W/cfm = 0.379 assumed 3 ton	ErRul	Com	tons	$3,038.37	29.66	$90.13	$2,673.63	$1,763.99	$7,476.00	$0.00	$1,012.79	$891.21	$333.69	$762.93	$2,237.69	$0.00	$0.00
	121	Measure	Pkg AC SEER = 14.0 (< 65 kBtuh, 3ph), EER = 12.04, Clg EIR = 0.2456, Supply Fan W/cfm = 0.306 assumed 3 ton	ErRobNc	Com	tons	$3,400.14	29.66	$90.13	$2,673.63	$1,763.99	$7,837.76	$361.77	$1,133.38	$891.21	$333.69	$762.93	$2,358.28	$120.59	$0.00
	122	Baseline	Pkg AC SEER = 13.0 (55-64 kBtuh), EER = 11.06, Clg EIR = 0.2557, Supply Fan W/cfm = 0.379; no Econo; 2-spd Fan assumed 5 ton	ErRul	Com	tons	$3,814.47	31.35	$90.13	$2,825.95	$2,431.36	$9,071.79	-	$762.89	$565.19	$333.69	$762.93	$1,661.77	-	-
	122	Measure	Pkg AC SEER = 13.0 (55-64 kBTUh), EER = 11.06, Clg EIR = 0.2557, Supply Fan W/cfm = 0.379; no Econo; 2-spd Fan assumed 5 ton	ErRul	Com	tons	$3,814.47	31.35	$90.13	$2,825.95	$2,431.36	$9,071.79	$0.00	$762.89	$565.19	$333.69	$762.93	$1,661.77	$0.00	$0.00
	123	Baseline	Pkg AC SEER = 14.0 (55-64 kBtuh), EER = 12.04, Clg EIR = 0.2456, Supply Fan W/cfm = 0.306; no Econo; 2-spd Fan assumed 5 ton	ErRobNc	Com	tons	$4,176.24	31.35	$90.13	$2,825.95	$2,431.36	$9,433.56	-	$835.25	$565.19	$333.69	$762.93	$1,734.13	-	-
	123	Measure	Pkg AC SEER = 14.0 (55-64 kBTUh), EER = 12.04, Clg EIR = 0.2456, Supply Fan W/cfm = 0.306; no Econo; 2-spd Fan assumed 5 ton	ErRobNc	Com	tons	$4,176.24	31.35	$90.13	$2,825.95	$2,431.36	$9,433.56	$0.00	$835.25	$565.19	$333.69	$762.93	$1,734.13	$0.00	$0.00

	Measure Information						Total Costs							Per Unit Costs						
Technology	READI Index ID	Match Pair	Description	Measure Type	Sector	Unit	Equipment Cost	Labor Hours	CA Average Labor Rate	Labor Cost	Misc. Costs	Full Installed Cost	Incremental Cost	Equipment Cost per unit	Labor Cost per Unit	Misc. Costs Per Unit	Misc. Fixed Costs per Project	Full Cost per Unit	Incremental Cost per Unit	Incremental Fixed Cost per Project
Large Packaged DX (> 5 tons)	94 - 99	Baseline	Pkg AC EER = 11.00; Clg EIR = 0.257; Supply Fan W/cfm = 0.298; Cond Fan W/Btuh = 0.0053; no econo assumed 6 ton	ErRul/ErRobNc	Com	tons	$4,337.30	32.20	$90.13	$2,902.11	$2,686.42	$9,925.83	-	$722.88	$483.69	$320.58	$762.93	$1,527.15	-	-
	94	Measure	Pkg AC EER = 11.0 (65-89 kBtuh), Clg EIR = 0.2570, Supply Fan W/cfm = 0.298, Cond Fan W/Btuh = 0.0053 assumed 6 ton	ErRul	Com	tons	$4,337.30	32.20	$90.13	$2,902.11	$2,686.42	$9,925.83	$0.00	$722.88	$483.69	$320.58	$762.93	$1,527.15	$0.00	$0.00
	95	Measure	Pkg AC EER = 11.5 (65-89 kBtuh), Clg EIR = 0.2401, Supply Fan W/cfm = 0.248, Cond Fan W/Btuh = 0.0060 assumed 6 ton	ErRobNc	Com	tons	$5,724.63	32.20	$90.13	$2,902.11	$2,686.42	$11,313.16	$1,387.34	$954.11	$483.69	$320.58	$762.93	$1,758.37	$231.22	$0.00
	96	Measure	Pkg AC EER = 12.0 (65-89 kBtuh), Clg EIR = 0.2304, Supply Fan W/cfm = 0.238, Cond Fan W/Btuh = 0.0057 assumed 6 ton	ErRobNc	Com	tons	$7,111.97	32.20	$90.13	$2,902.11	$2,686.42	$12,700.50	$2,774.67	$1,185.33	$483.69	$320.58	$762.93	$1,989.59	$462.45	$0.00
	97	Measure	Pkg AC EER = 11.0 (65-109 kBTUh), Clg EIR = 0.2570, Supply Fan W/cfm = 0.298, Cond Fan W/Btuh = 0.0053; w/Econo; 2-spd Fan assumed 6 ton	ErRul	Com	tons	$4,337.30	32.20	$90.13	$2,902.11	$2,686.42	$9,925.83	$0.00	$722.88	$483.69	$320.58	$762.93	$1,527.15	$0.00	$0.00
	98	Measure	Pkg AC EER = 11.5 (65-109 kBTUh), Clg EIR = 0.2401, Supply Fan W/cfm = 0.248, Cond Fan W/Btuh = 0.0060; w/Econo; 2-spd Fan assumed 6 ton	ErRobNc	Com	tons	$5,724.63	32.20	$90.13	$2,902.11	$2,686.42	$11,313.16	$1,387.34	$954.11	$483.69	$320.58	$762.93	$1,758.37	$231.22	$0.00
	99	Measure	Pkg AC EER = 12.0 (65-109 kBTUh), Clg EIR = 0.2304, Supply Fan W/cfm = 0.238, Cond Fan W/Btuh = 0.0057; w/Econo; 2-spd Fan assumed 6 ton	ErRobNc	Com	tons	$7,111.97	32.20	$90.13	$2,902.11	$2,686.42	$12,700.50	$2,774.67	$1,185.33	$483.69	$320.58	$762.93	$1,989.59	$462.45	$0.00
	100 - 105	Baseline	Pkg AC EER = 11.00; Clg EIR = 0.257; Supply Fan W/cfm = 0.298; Cond Fan W/Btuh = 0.0053; w/ econo assumed 10 ton	ErRul/ErRobNc	Com	tons	$8,938.39	35.58	$90.13	$3,206.75	$3,968.74	$16,113.88	-	$893.84	$320.68	$320.58	$762.93	$1,535.10	-	-
	100	Measure	Pkg AC EER = 11.0 (90-134 kBtuh), Clg EIR = 0.2570, Supply Fan W/cfm = 0.298, Cond Fan W/Btuh = 0.0053 assumed 10 ton	ErRul	Com	tons	$8,938.39	35.58	$90.13	$3,206.75	$3,968.74	$16,113.88	$0.00	$893.84	$320.68	$320.58	$762.93	$1,535.10	$0.00	$0.00
	101	Measure	Pkg AC EER = 11.5 (90-134 kBtuh), Clg EIR = 0.2401, Supply Fan W/cfm = 0.248, Cond Fan W/Btuh = 0.0060 assumed 10 ton	ErRobNc	Com	tons	$10,325.72	35.58	$90.13	$3,206.75	$3,968.74	$17,501.22	$1,387.34	$1,032.57	$320.68	$320.58	$762.93	$1,673.83	$138.73	$0.00
	102	Measure	Pkg AC EER = 12.0 (90-134 kBtuh), Clg EIR = 0.2304, Supply Fan W/cfm = 0.238, Cond Fan W/Btuh = 0.0057 assumed 10 ton	ErRobNc	Com	tons	$11,713.06	35.58	$90.13	$3,206.75	$3,968.74	$18,888.55	$2,774.67	$1,171.31	$320.68	$320.58	$762.93	$1,812.56	$277.47	$0.00
	103	Measure	Pkg AC EER = 11.0 (110-134 kBTUh), Clg EIR = 0.2570, Supply Fan W/cfm = 0.298, Cond Fan W/Btuh = 0.0053; w/Econo; 2-spd Fan assumed 10 ton	ErRul	Com	tons	$8,938.39	35.58	$90.13	$3,206.75	$3,968.74	$16,113.88	$0.00	$893.84	$320.68	$320.58	$762.93	$1,535.10	$0.00	$0.00
	104	Measure	Pkg AC EER = 11.5 (110-134 kBTUh), Clg EIR = 0.2401, Supply Fan W/cfm = 0.248, Cond Fan W/Btuh = 0.0060; w/Econo; 2-spd Fan assumed 10 ton	ErRobNc	Com	tons	$10,325.72	35.58	$90.13	$3,206.75	$3,968.74	$17,501.22	$1,387.34	$1,032.57	$320.68	$320.58	$762.93	$1,673.83	$138.73	$0.00
	105	Measure	Pkg AC EER = 12.0 (110-134 kBTUh), Clg EIR = 0.2304, Supply Fan W/cfm = 0.238, Cond Fan W/Btuh = 0.0057; w/Econo; 2-spd Fan assumed 10 ton	ErRobNc	Com	tons	$11,713.06	35.58	$90.13	$3,206.75	$3,968.74	$18,888.55	$2,774.67	$1,171.31	$320.68	$320.58	$762.93	$1,812.56	$277.47	$0.00
	106 - 108	Baseline	Pkg AC EER = 10.8 (135-239 kBtuh), Clg EIR = 0.2622, Supply Fan W/cfm = 0.270, Cond Fan W/Btuh = 0.0053; w/Econo; 2-spd Fan assumed 15 ton	ErRul/ErRobNc	Com	tons	$14,134.81	39.80	$90.13	$3,587.55	$5,571.65	$23,294.02	-	$942.32	$239.17	$320.58	$762.93	$1,502.07	-	-
	106	Measure	Pkg AC EER = 10.8 (135-239 kBtuh), Clg EIR = 0.2622, Supply Fan W/cfm = 0.270, Cond Fan W/Btuh = 0.0053; w/Econo; 2-spd Fan assumed 15 ton	ErRobNc	Com	tons	$14,134.81	39.80	$90.13	$3,587.55	$5,571.65	$23,294.02	$0.00	$942.32	$239.17	$320.58	$762.93	$1,502.07	$0.00	$0.00
	107	Measure	Pkg AC EER = 11.5 (135-239 kBTUh), Clg EIR = 0.2439, Supply Fan W/cfm = 0.233, Cond Fan W/Btuh = 0.0064; w/Econo; 2-spd Fan assumed 15 ton	ErRobNc	Com	tons	$16,077.08	39.80	$90.13	$3,587.55	$5,571.65	$25,236.29	$1,942.27	$1,071.81	$239.17	$320.58	$762.93	$1,631.56	$129.48	$0.00
	108	Measure	Pkg AC EER = 12.0 (135-239 kBTUh), Clg EIR = 0.2307, Supply Fan W/cfm = 0.165, Cond Fan W/Btuh = 0.0089; w/Econo; 2-spd Fan assumed 15 ton	ErRul	Com	tons	$17,464.42	39.80	$90.13	$3,587.55	$5,571.65	$26,623.62	$3,329.61	$1,164.29	$239.17	$320.58	$762.93	$1,724.05	$221.97	$0.00
	109 - 111	Baseline	Pkg AC EER = 9.8 (240-759 kBtuh); w/Econo; 2-spd Fan assumed 40 ton	ErRul/ErRobNc	Com	tons	$40,116.94	60.93	$90.13	$5,491.56	$13,586.18	$59,194.68	-	$1,002.92	$137.29	$320.58	$762.93	$1,460.79	-	-
	109	Measure	Pkg AC EER = 10.5 (240-759 kBTUh); w/Econo; 2-spd Fan assumed 40 ton	ErRul	Com	tons	$42,059.21	60.93	$90.13	$5,491.56	$13,586.18	$61,136.95	$1,942.27	$1,051.48	$137.29	$320.58	$762.93	$1,509.35	$48.56	$0.00
	110	Measure	Pkg AC EER = 10.8 (240-759 kBTUh); w/Econo; 2-spd Fan assumed 40 ton	ErRobNc	Com	tons	$42,891.61	60.93	$90.13	$5,491.56	$13,586.18	$61,969.35	$2,774.67	$1,072.29	$137.29	$320.58	$762.93	$1,530.16	$69.37	$0.00
	111	Measure	Pkg AC EER = 9.8 (240-759 kBTUh); w/Econo; 2-spd Fan assumed 40 ton	ErRobNc	Com	tons	$40,116.94	60.93	$90.13	$5,491.56	$13,586.18	$59,194.68	$0.00	$1,002.92	$137.29	$320.58	$762.93	$1,460.79	$0.00	$0.00
	112 - 114	Baseline	Pkg AC EER = 9.5 (>= 760 kBtuh); w/Econo; 2-spd Fan assumed 100 ton	ErRul/ErRobNc	Com	tons	$108,300.86	111.63	$90.13	$10,061.18	$32,821.05	$151,183.09	-	$1,083.01	$100.61	$320.58	$762.93	$1,504.20	-	-
	112	Measure	Pkg AC EER = 10.2 (>= 760 kBTUh); w/Econo; 2-spd Fan assumed 100 ton	ErRobNc	Com	tons	$110,243.13	111.63	$90.13	$10,061.18	$32,821.05	$153,125.36	$1,942.27	$1,102.43	$100.61	$320.58	$762.93	$1,523.62	$19.42	$0.00
	113	Measure	Pkg AC EER = 9.5 (>= 760 kBTUh); w/Econo; 2-spd Fan assumed 100 ton	ErRul	Com	tons	$108,300.86	111.63	$90.13	$10,061.18	$32,821.05	$151,183.09	$0.00	$1,083.01	$100.61	$320.58	$762.93	$1,504.20	$0.00	$0.00
	114	Measure	Pkg AC EER = 9.7 (>= 760 kBTUh); w/Econo; 2-spd Fan assumed 100 ton	ErRobNc	Com	tons	$108,855.79	111.63	$90.13	$10,061.18	$32,821.05	$151,738.02	$554.93	$1,088.56	$100.61	$320.58	$762.93	$1,509.75	$5.55	$0.00
	1175	Baseline	Pkg AC EER = 9.50; w/ furnace; w/ econo units with furnace out of sample	ErRobNc	Com	tons														
	1175	Measure	Pkg AC EER = 10.0 (>= 760 kBTUh) - Combined EER 9.7 and EER 10.2	ErRobNc	Com	tons														
Air-Cooled Chillers	93	Baseline	Air cooled package screw chiller (1.260 kW/ton) assumed 100 ton ground mount	ErRobNc	Com	ton	$50,172.59	79.50	$89.12	$7,085.07	$19,943.50	$77,201.16	-	$501.73	$70.85	227.41875	1750	$800.00	-	-
	93	Measure	Air cooled screw chiller (1.008 kW/ton) assumed 100 ton ground mount	ErRobNc	Com	ton	$85,793.85	79.50	$89.12	$7,085.07	$19,943.50	$112,822.42	$35,621.26	$857.94	$70.85	227.41875	1750	$1,156.21	$356.21	0

	Measure Information						Total Costs							Per Unit Costs						
Technology	READI Index ID	Match Pair	Description	Measure Type	Sector	Unit	Equipment Cost	Labor Hours	CA Average Labor Rate	Labor Cost	Misc. Costs	Full Installed Cost	Incremental Cost	Equipment Cost per unit	Labor Cost per Unit	Misc. Costs Per Unit	Misc. Fixed Costs per Project	Full Cost per Unit	Incremental Cost per Unit	Incremental Fixed Cost per Project
Water-Cooled Chillers (excluding centrifugal VSD)	77	Baseline	Water cooled centrifugal chiller (0.634 kW/ton) assumed 100 ton ground mount	ErRobNc	Com	ton	$52,207.89	114.50	$89.36	$10,232.29	$27,237.89	$89,678.07	-	$522.08	$102.32	254.878875	1750	$879.28	-	-
	77	Measure	Water cooled centrifugal chiller (< 150 tons, 0.560 kW/ton) assumed 100 ton ground mount	ErRobNc	Com	ton	$69,997.19	114.50	$89.36	$10,232.29	$27,237.89	$107,467.37	$17,789.30	$699.97	$102.32	254.878875	1750	$1,057.17	$177.89	0
	81	Baseline	Water cooled centrifugal chiller (0.634 kW/ton) assumed 200 ton roof mount	ErRobNc	Com	ton	$82,362.99	171.00	$89.36	$15,281.41	$50,755.78	$148,400.18	-	$411.81	$76.41	228.778875	5000	$717.00	-	-
	81	Measure	Water cooled centrifugal chiller (150-299 tons, 0.507 kW/ton) assumed 200 ton roof mount	ErRobNc	Com	ton	$112,893.27	171.00	$89.36	$15,281.41	$50,755.78	$178,930.46	$30,530.28	$564.47	$76.41	228.778875	5000	$869.65	$152.65	0
	83	Baseline	Water cooled centrifugal chiller (0.573 kW/ton) assumed 300 ton basement mount	ErRobNc	Com	ton	$127,182.24	222.00	$89.36	$19,839.03	$67,481.22	$214,502.49	-	$423.94	$66.13	198.895729	7812.5	$688.97	-	-
	83	Measure	Water cooled centrifugal chiller (>= 300 tons, 0.461 kW/ton) assumed 300 ton basement mount	ErRobNc	Com	ton	$154,106.59	222.00	$89.36	$19,839.03	$67,481.22	$241,426.83	$26,924.35	$513.69	$66.13	198.895729	7812.5	$778.71	$89.75	0
	90	Baseline	Water cooled screw chiller (0.778 kW/ton) assumed 100 ton ground mount	RobNc	Com	ton	$39,786.44	114.50	$89.36	$10,232.29	$27,237.89	$77,256.62	-	$397.86	$102.32	254.878875	1750	$755.07	-	-
	90	Measure	Water cooled screw chiller (< 150 tons, 0.632 kW/ton) assumed 100 ton ground mount	RobNc	Com	ton	$74,884.25	114.50	$89.36	$10,232.29	$27,237.89	$112,354.42	$35,097.81	$748.84	$102.32	254.878875	1750	$1,106.04	$350.98	0
	91	Baseline	Water cooled screw chiller (0.68 kW/ton) assumed 200 ton roof mount	ErRobNc	Com	ton	$93,500.34	171.00	$89.36	$15,281.41	$50,755.78	$159,537.53	-	$467.50	$76.41	228.778875	5000	$772.69	-	-
	91	Measure	Water cooled screw chiller (150-299 tons, 0.574 kW/ton) assumed 200 ton roof mount	ErRobNc	Com	ton	$118,982.31	171.00	$89.36	$15,281.41	$50,755.78	$185,019.50	$25,481.97	$594.91	$76.41	228.778875	5000	$900.10	$127.41	0
	92	Baseline	Water cooled screw chiller (0.62 kW/ton) assumed 300 ton basement mount	ErRobNc	Com	ton	$138,079.20	222.00	$89.36	$19,839.03	$67,481.22	$225,399.44	-	$460.26	$66.13	198.895729	7812.5	$725.29	-	-
	92	Measure	Water cooled screw chiller (>= 300 tons, 0.511 kW/ton) assumed 300 ton basement mount	ErRobNc	Com	ton	$164,282.35	222.00	$89.36	$19,839.03	$67,481.22	$251,602.60	$26,203.16	$547.61	$66.13	198.895729	7812.5	$812.63	$87.34	0
Water-Cooled Centrifugal VSD Chillers (>= 300 tons)	78, 79, 80	Baseline	Water cooled centrifugal chiller (0.634 kW/ton) assumed 100 ton - out of sample	ErRobNc	Com	ton														
	78	Measure	Water cooled VSD centrifugal chiller (< 150 tons, 0.560 kW/ton), load control tower assumed 100 ton - out of sample	ErRobNc	Com	ton														
	79	Measure	Water cooled centrifugal chiller (< 150 tons, 0.700 kW/ton, 1 frictionless compressor(s) w/ VSD) assumed 100 ton - out of sample	ErRobNc	Com	ton														
	80	Measure	Water cooled centrifugal chiller (< 150 tons, 0.700 kW/ton, >1 frictionless compressor(s) w/ VSD) assumed 100 ton - out of sample	ErRobNc	Com	ton														
	82	Baseline	Water cooled centrifugal chiller (0.634 kW/ton) assumed 200 ton roof - out of sample	ErRobNc	Com	ton														
	82	Measure	Water cooled VSD centrifugal chiller (150-299 tons, 0.507 kW/ton), load control tower assumed 200 ton roof - out of sample	ErRobNc	Com	ton														
	84	Baseline	Water cooled centrifugal chiller (0.573 kW/ton) assumed 300 ton basement mount	ErRobNc	Com	ton	$127,182.24	222.00	$89.36	$19,839.03	$67,481.22	$214,502.49	-	$423.94	$66.13	$198.90	$7,812.50	$688.97	-	-
	84	Measure	Water cooled VSD centrifugal chiller (>= 300 tons, 0.461 kW/ton), load control tower assumed 300 ton basement mount	ErRobNc	Com	ton	$196,657.25	222.00	$89.12	$19,784.71	$67,481.22	$283,923.18	$69,420.69	$655.52	$65.95	$198.90	$7,812.50	$920.37	$231.40	0
Small Packaged HP (< 65,000 Btuh)	49 - 60	Baseline	Multiple Base Efficiency technologies based on building vintage	ErRobNc	Com	MBH	TBD	TBD	TBD	TBD	TBD	TBD	-	TBD	TBD	TBD	TBD	TBD	-	-
	49	Measure	Pkg HP SEER = 14.5 (< 55 kBTUh) - Combined SEER 14 and SEER 15 hp assumed 36 MBH	ErRobNc	Com	MBH	$3,965.92	18.81	$90.24	$1,697.64	$2,058.51	$7,722.07	TBD	$110.16	$47.16	$35.99	$762.93	$193.31	TBD	TBD
	50	Measure	Pkg HP SEER = 13.0 (< 65 kbtuh), EER = 11.07, HSPF = 7.70, COP = 3.28 assumed 36 MBH	ErRul	Com	MBH	$3,327.08	18.81	$90.24	$1,697.64	$2,058.51	$7,083.23	TBD	$92.42	$47.16	$35.99	$762.93	$175.56	TBD	TBD
	51	Measure	Pkg HP SEER = 14.0 (< 65 kbtuh), EER = 11.6, HSPF = 8.00, COP = 3.52 assumed 36 MBH	ErRobNc	Com	MBH	$3,752.97	18.81	$90.24	$1,697.64	$2,058.51	$7,509.12	TBD	$104.25	$47.16	$35.99	$762.93	$187.39	TBD	TBD
	52	Measure	Pkg HP SEER = 14.5 (< 65 kBtuh) - Combined SEER 14 and SEER 15 hp assumed 36 MBH	ErRobNc	Com	MBH	$3,965.92	18.81	$90.24	$1,697.64	$2,058.51	$7,722.07	TBD	$110.16	$47.16	$35.99	$762.93	$193.31	TBD	TBD
	53	Measure	Pkg HP SEER = 15.0 (< 65 kbtuh), EER = 12.0, HSPF = 8.50, COP = 3.74 assumed 36 MBH	ErRobNc	Com	MBH	$4,178.86	18.81	$90.24	$1,697.64	$2,058.51	$7,935.01	TBD	$116.08	$47.16	$35.99	$762.93	$199.22	TBD	TBD
	54	Measure	Pkg HP SEER = 13.0 (< 55 kBTUh), EER = 11.07, HSPF = 7.70, COP = 3.28; no Econo; 1-spd Fan assumed 36 MBH	ErRobNc	Com	MBH	$3,327.08	18.81	$90.24	$1,697.64	$2,058.51	$7,083.23	TBD	$92.42	$47.16	$35.99	$762.93	$175.56	TBD	TBD
	55	Measure	Pkg HP SEER = 14.0 (< 55 kBTUh), EER = 11.6, HSPF = 8.00, COP = 3.52; no Econo; 1-spd Fan assumed 36 MBH	ErRobNc	Com	MBH	$3,752.97	18.81	$90.24	$1,697.64	$2,058.51	$7,509.12	TBD	$104.25	$47.16	$35.99	$762.93	$187.39	TBD	TBD
	56	Measure	Pkg HP SEER = 15.0 (< 55 kBTUh), EER = 12.0, HSPF = 8.50, COP = 3.74; no Econo; 1-spd Fan assumed 36 MBH	ErRobNc	Com	MBH	$4,178.86	18.81	$90.24	$1,697.64	$2,058.51	$7,935.01	TBD	$116.08	$47.16	$35.99	$762.93	$199.22	TBD	TBD
	57	Measure	Pkg HP SEER = 14.5 (55-64 kBTUh) - Combined SEER 14 and SEER 15 hp assumed 60 MBH	ErRobNc	Com	MBH	$4,682.84	31.35	$90.24	$2,829.40	$2,922.23	$10,434.46	TBD	$78.05	$47.16	$35.99	$762.93	$161.19	TBD	TBD
	58	Measure	Pkg HP SEER = 13.0 (55-64 kBTUh), EER = 11.07, HSPF = 7.70, COP = 3.28; w/Econo; 2-spd Fan assumed 60 MBH	ErRobNc	Com	MBH	$4,044.00	31.35	$90.24	$2,829.40	$2,922.23	$9,795.63	TBD	$67.40	$47.16	$35.99	$762.93	$150.54	TBD	TBD
	59	Measure	Pkg HP SEER = 14.0 (55-64 kBTUh), EER = 11.6, HSPF = 8.00, COP = 3.52; w/Econo; 2-spd Fan assumed 60 MBH	ErRobNc	Com	MBH	$4,469.89	31.35	$90.24	$2,829.40	$2,922.23	$10,221.52	TBD	$74.50	$47.16	$35.99	$762.93	$157.64	TBD	TBD
	60	Measure	Pkg HP SEER = 15.0 (55-64 kBTUh), EER = 12.0, HSPF = 8.50, COP = 3.74; w/Econo; 2-spd Fan assumed 60 MBH	ErRobNc	Com	MBH	$4,895.78	31.35	$90.24	$2,829.40	$2,922.23	$10,647.41	TBD	$81.60	$47.16	$35.99	$762.93	$164.74	TBD	TBD

	Measure Information						Total Costs							Per Unit Costs						
Technology	READI Index ID	Match Pair	Description	Measure Type	Sector	Unit	Equipment Cost	Labor Hours	CA Average Labor Rate	Labor Cost	Misc. Costs	Full Installed Cost	Incremental Cost	Equipment Cost per unit	Labor Cost per Unit	Misc. Costs Per Unit	Misc. Fixed Costs per Project	Full Cost per Unit	Incremental Cost per Unit	Incremental Fixed Cost per Project
Large Packaged HP (65,000 - 240,000 Btuh)	29 - 40	Baseline	Multiple Base Efficiency technologies based on building vintage	ErRobNc	Com	MBH	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	-	-
	29	Measure	Pkg HP EER = 11.5 (65-89 kBtuh), COP = 3.4 assumed 72 MBH ground mount	ErRobNc	Com	MBH	$8,045.01	26.80	$90.46	$2,424.37	$3,221.64	$13,691.02	TBD	$111.74	$33.67	$34.15	$762.93	$179.56	TBD	TBD
	30	Measure	Pkg HP EER = 12.0 (65-89 kBtuh), COP = 3.4 assumed 72 MBH ground mount	ErRobNc	Com	MBH	$9,019.27	26.80	$90.46	$2,424.37	$3,221.64	$14,665.28	TBD	$125.27	$33.67	$34.15	$762.93	$193.09	TBD	TBD
	31	Measure	Pkg HP EER = 11.5 (65-109 kBTUh), COP = 3.4; w/Econo; 2-spd Fan assumed 72 MBH ground mount	ErRobNc	Com	MBH	$8,045.01	26.80	$90.46	$2,424.37	$3,221.64	$13,691.02	TBD	$111.74	$33.67	$34.15	$762.93	$179.56	TBD	TBD
	32	Measure	Pkg HP EER = 12.0 (65-109 kBTUh), COP = 3.4; w/Econo; 2-spd Fan assumed 72 MBH ground mount	ErRobNc	Com	MBH	$9,019.27	26.80	$90.46	$2,424.37	$3,221.64	$14,665.28	TBD	$125.27	$33.67	$34.15	$762.93	$193.09	TBD	TBD
	33	Measure	Pkg HP EER = 11.5 (90-134 kBtuh), COP = 3.4 assumed 120 MBH ground mount	ErRobNc	Com	MBH	$13,166.06	44.67	$90.46	$4,040.61	$4,860.78	$22,067.45	TBD	$109.72	$33.67	$34.15	$762.93	$177.54	TBD	TBD
	34	Measure	Pkg HP EER = 12.0 (90-134 kBtuh), COP = 3.4 assumed 120 MBH ground mount	ErRobNc	Com	MBH	$14,140.31	44.67	$90.46	$4,040.61	$4,860.78	$23,041.71	TBD	$117.84	$33.67	$34.15	$762.93	$185.66	TBD	TBD
	35	Measure	Pkg HP EER = 11.5 (110-134 kBTUh), COP = 3.4; w/Econo; 2-spd Fan assumed 120 MBH ground mount	ErRobNc	Com	MBH	$13,166.06	44.67	$90.46	$4,040.61	$4,860.78	$22,067.45	TBD	$109.72	$33.67	$34.15	$762.93	$177.54	TBD	TBD
	36	Measure	Pkg HP EER = 12.0 (110-134 kBTUh), COP = 3.4; w/Econo; 2-spd Fan assumed 120 MBH ground mount	ErRobNc	Com	MBH	$14,140.31	44.67	$90.46	$4,040.61	$4,860.78	$23,041.71	TBD	$117.84	$33.67	$34.15	$762.93	$185.66	TBD	TBD
	37	Measure	Pkg HP EER = 11.5 (135-239 kBtuh), COP = 3.2 assumed 180 MBH roof mount	ErRobNc	Com	MBH	$19,567.36	62.00	$90.02	$5,581.25	$7,122.63	$32,271.24	TBD	$108.71	$31.01	$35.33	$762.93	$175.05	TBD	TBD
	38	Measure	Pkg HP EER = 12.0 (135-239 kBtuh), COP = 3.2 assumed 180 MBH roof mount	ErRobNc	Com	MBH	$20,541.62	62.00	$90.02	$5,581.25	$7,122.63	$33,245.50	TBD	$114.12	$31.01	$35.33	$762.93	$180.46	TBD	TBD
	39	Measure	Pkg HP EER = 10.8 (135-239 kBTUh), COP = 3.2; w/Econo; 2-spd Fan assumed 180 MBH roof mount	ErRobNc	Com	MBH	$18,203.40	62.00	$90.02	$5,581.25	$7,122.63	$30,907.28	TBD	$101.13	$31.01	$35.33	$762.93	$167.47	TBD	TBD
	40	Measure	Pkg HP EER = 10.8 (135-239 kBTUh), COP = 3.2; w/Econo; 2-spd Fan assumed 180 MBH roof mount	ErRobNc	Com	MBH	$18,203.40	62.00	$90.02	$5,581.25	$7,122.63	$30,907.28	TBD	$101.13	$31.01	$35.33	$762.93	$167.47	TBD	TBD
	41	Measure	Pkg HP EER = 10.5 (240-759 kBtuh), COP = 3.2 - out of sample	ErRobNc	Com	MBH														
	42	Measure	Pkg HP EER = 10.8 (240-759 kBtuh), COP = 3.2 - out of sample	ErRobNc	Com	MBH														
	43	Measure	Pkg HP EER = 10.5 (240-759 kBTUh), COP = 3.2; w/Econo; 2-spd Fan - out of sample	ErRobNc	Com	MBH														
	44	Measure	Pkg HP EER = 10.8 (240-759 kBTUh), COP = 3.2; w/Econo; 2-spd Fan - out of sample	ErRobNc	Com	MBH														
	45	Measure	Pkg HP EER = 10.0 (>= 760 kBtuh), COP = 3.2 - out of sample	ErRobNc	Com	MBH														
	46	Measure	Pkg HP EER = 10.2 (>= 760 kBtuh), COP = 3.2 - out of sample	ErRobNc	Com	MBH														
	47	Measure	Pkg HP EER = 10.0 (>= 760 kBTUh), COP = 3.2; w/Econo; 2-spd Fan - out of sample	ErRobNc	Com	MBH														
	48	Measure	Pkg HP EER = 10.2 (>= 760 kBTUh), COP = 3.2; w/Econo; 2-spd Fan - out of sample	ErRobNc	Com	MBH														
Steam Boilers (non-process)	155, 156	Baseline	Steam boiler (<300 kBtuh, 80.0% AFUE, atmospheric) assumed 250 MBH ground mount	RobNc	Com	MBH	$1,525.55	145.00	$90.95	$13,188.00	$11,264.95	$25,978.51	-	$6.10	$52.75	$45.06	$0.00	$103.91	-	-
	155	Measure	Steam boiler (< 300 kBTUh, 82.0 AFUE, atmospheric) assumed 250 MBH ground mount	RobNc	Com	MBH	$11,535.85	145.00	$90.95	$13,188.00	$11,264.95	$35,988.81	$10,010.30	$46.14	$52.75	$45.06	$0.00	$143.96	$40.04	$0.00
	156	Measure	Steam boiler (< 300 kBTUh, 82.0 AFUE, forced draft) assumed 250 MBH ground mount	RobNc	Com	MBH	$11,535.85	145.00	$90.95	$13,188.00	$11,264.95	$35,988.81	$10,010.30	$46.14	$52.75	$45.06	$0.00	$143.96	$40.04	$0.00
	157	Baseline	Steam boiler (300-2500 kBtuh, 77.0% thermal efficiency, atmospheric) assumed 1400 MBH basement mount	RobNc	Com	MBH	$4,870.86	223.30	$90.95	$20,309.53	$28,409.16	$53,589.55	-	$3.48	$14.51	$18.56	$2,422.50	$36.55	-	-
	157	Measure	Steam boiler (300-2500 kBTUh, 85.0% thermal efficiency, atmospheric) assumed 1400 MBH basement mount	RobNc	Com	MBH	$44,912.07	223.30	$90.95	$20,309.53	$28,409.16	$93,630.76	$40,041.21	$32.08	$14.51	$18.56	$2,422.50	$65.15	$28.60	$0.00
	158	Baseline	Steam boiler (300-2500 kBtuh, 79.0% thermal efficiency, forced draft) assumed 1400 MBH basement mount	RobNc	Com	MBH	$14,881.16	223.30	$90.95	$20,309.53	$28,409.16	$63,599.85	-	$10.63	$14.51	$18.56	$2,422.50	$43.70	-	-
	158	Measure	Steam boiler (300-2500 kBTUh, 85.0% thermal efficiency, forced draft) assumed 1400 MBH basement mount	RobNc	Com	MBH	$44,912.07	223.30	$90.95	$20,309.53	$28,409.16	$93,630.76	$30,030.91	$32.08	$14.51	$18.56	$2,422.50	$65.15	$21.45	$0.00
	159	Baseline	Steam boiler (> 2500 kBtuh, 77.0% combustion efficiency, atmospheric) assumed 3000 MBH roof mount	RobNc	Com	MBH	$30,416.26	167.50	$90.95	$15,234.42	$37,860.12	$83,510.81	-	$10.14	$5.08	$11.45	$3,506.25	$26.67	-	-
	159	Measure	Steam boiler (> 2500 kBTUh, 80.0% combustion efficiency, atmospheric) assumed 3000 MBH roof mount	RobNc	Com	MBH	$45,431.72	167.50	$90.95	$15,234.42	$37,860.12	$98,526.26	$15,015.46	$15.14	$5.08	$11.45	$3,506.25	$31.67	$5.01	$0.00
	160	Baseline	Steam boiler (> 2500 kBtuh, 79.0% combustion efficiency, forced draft) assumed 3000 MBH roof mount	RobNc	Com	MBH	$40,426.57	167.50	$90.95	$15,234.42	$37,860.12	$93,521.11	-	$13.48	$5.08	$11.45	$3,506.25	$30.00	-	-
	160	Measure	Steam boiler (> 2500 kBTUh, 80.0% combustion efficiency, forced draft) assumed 3000 MBH roof mount	RobNc	Com	MBH	$45,431.72	167.50	$90.95	$15,234.42	$37,860.12	$98,526.26	$5,005.15	$15.14	$5.08	$11.45	$3,506.25	$31.67	$1.67	$0.00
	100098	Baseline	Steam boiler (300-2500 kBtuh, 80.0% thermal efficiency, atmospheric) assumed 1400 MBH basement mount	RobNc	Res	MBH	$19,886.31	223.30	$90.95	$20,309.53	$28,409.16	$68,605.00	-	$14.20	$14.51	$18.56	$2,422.50	$47.27	-	-
	100098	Measure	Steam boiler (300-2500 kBTUh, 85.0% thermal efficiency, atmospheric) assumed 1400 MBH basement mount	RobNc	Res	MBH	$44,912.07	223.30	$90.95	$20,309.53	$28,409.16	$93,630.76	$25,025.76	$32.08	$14.51	$18.56	$2,422.50	$65.15	$17.88	$0.00
Waterside Economizers	9079	Baseline	T24 minimum: no water economizer	RobNc	Com	ton	$0.00	0.00	$0.00	$0.00	$0.00	$0.00	-	$0.00	$0.00	$0.00	$0.00	$0.00	-	-
	9079	Measure	Non integrated evaporator precooler heat exchanger assumed 100 ton capacity 2- 100ft 4" pipe runs	RobNc	Com	ton	$16,743.13	366.50	$90.35	$33,113.69	$67,149.15	$117,005.97	$117,005.97	$167.43	$331.14	$433.07	$18,700.00	$931.63	$931.63	$18,700.00
	9079	Measure	Non integrated evaporator precooler heat exchanger assumed 300 ton capacity 100ft 8" pipe runs	RobNc	Com	ton	$37,318.79	506.50	$90.35	$45,762.85	$98,306.96	$181,388.60	$181,388.60	$124.40	$152.54	$243.96	$19,700.00	$520.90	$520.90	$19,700.00

	Measure Information						Total Costs							Per Unit Costs						
Technology	READI Index ID	Match Pair	Description	Measure Type	Sector	Unit	Equipment Cost	Labor Hours	CA Average Labor Rate	Labor Cost	Misc. Costs	Full Installed Cost	Incremental Cost	Equipment Cost per unit	Labor Cost per Unit	Misc. Costs Per Unit	Misc. Fixed Costs per Project	Full Cost per Unit	Incremental Cost per Unit	Incremental Fixed Cost per Project
Residential Water Heating																				
Tankless WH	341	Baseline	Small Gas Storage Water Heater 40 Gal, EF = 0.60, Recov Eff = 0.76	ErRobNc	Com	MBH														
	341	Measure	Small Gas Instantaneous Water Heater EF = 0.82, Recov Eff = 0.82 lte75kBtuh out of sample	ErRobNc	Com	MBH														
	376	Measure	High Efficiency Small Gas Instantaneous Water Heater lte75kBtuh out of sample	ErRobNc	Res	MBH														
	345, 346, 347, 100096, 100115	Baseline	Large Gas Storage Water Heater, Et = 0.80, Stdby Loss = 0.56%/hr assumed 100 MBH, 100 gal	ErRobNc	Com	MBH	$5,249.63	15.99	$74.31	$1,188.10	$0.00	$6,437.74	-	$21.00	$4.75	$0.00		$25.75	-	
	345	Measure	Large Gas Instantaneous Water Heater, Et = 0.80, Stdby Loss = 0.23%/hr gt200kBtuh assumed 240 MBH	ErRobNc	Com	MBH	$1,390.85	4.57	$81.42	$372.13	$0.00	$1,762.98	-$4,674.75	$5.56	$1.49	$0.00		$7.05	-$18.70	
	346, 100096, 100115	Measure	Large Gas Instantaneous Water Heater, Et = 0.85, Stdby Loss = 0.23%/hr gt200kBtuh assumed 240 MBH	ErRobNc	Com	MBH	$1,478.23	4.57	$81.42	$372.13	$0.00	$1,850.36	-$4,587.38	$5.91	$1.49	$0.00		$7.40	-$18.35	
	347	Measure	Large Gas Instantaneous Water Heater, Et = 0.90, Stdby Loss = 0.23%/hr gt200kBtuh assumed 240 MBH	ErRobNc	Com	MBH	$1,565.60	4.57	$81.42	$372.13	$0.00	$1,937.73	-$4,500.00	$6.26	$1.49	$0.00		$7.75	-$18.00	
	348, 349, 350	Baseline	Large Gas Storage Water Heater, Et = 0.80, Stdby Loss = 0.56%/hr assumed 75 MBH, 50 gal	ErRobNc	Com	MBH	$3,204.47	6.16	$74.31	$457.99	$0.00	$3,662.46	-	$32.04	$4.58	$0.00		$36.62	-	
	348	Measure	Medium Gas Instantaneous Water Heater, Et = 0.80, Stdby Loss = 0.05%/hr 76to200kBtuh assumed 175 MBH	ErRobNc	Com	MBH	$939.92	4.29	$81.42	$349.41	$0.00	$1,289.33	-$2,373.13	$9.40	$3.49	$0.00		$12.89	-$23.73	
	349	Measure	Medium Gas Instantaneous Water Heater, Et = 0.85, Stdby Loss = 0.05%/hr 76to200kBtuh assumed 175 MBH	ErRobNc	Com	MBH	$1,027.29	4.29	$81.42	$349.41	$0.00	$1,376.70	-$2,285.76	$10.27	$3.49	$0.00		$13.77	-$22.86	
	350	Measure	Medium Gas Instantaneous Water Heater, Et = 0.90, Stdby Loss = 0.05%/hr 76to200kBtuh assumed 175 MBH	ErRobNc	Com	MBH	$1,114.67	4.29	$81.42	$349.41	$0.00	$1,464.08	-$2,198.38	$11.15	$3.49	$0.00		$14.64	-$21.98	
	100113, 100118	Baseline	MF Large Gas Storage Water Heater, Et = 0.80, Stdby Loss = 0.56%/hr assumed 100 MBH, 100 gal	ErRobNc	Res	MBH	$5,249.63	15.99	$74.31	$1,188.10	$0.00	$6,437.74	-	$21.00	$4.75	$0.00		$25.75	-	
	100113, 100118	Measure	MF Large Gas Instantaneous Water Heater, Et = 0.85, Stdby Loss = 0.23%/hr gt300kBtuh assumed 350 MBH out of sample	ErRobNc	Res	MBH	$2,241.35	4.57	$81.42	$372.13	$0.00	$2,613.48	-$3,824.25	$6.40	$1.06	$0.00		$7.47	-$18.28	
	Example	Baseline	Small Gas Storage Water Heater 40 Gal; EF = 0.59; Recov Eff = 0.76	ErRobNc	Res	unit	$565.05	4.20	$78.19	$328.73	$0.00	$893.78	-							
	Example	Measure	High Efficiency Medium Gas Instantaneous Water heater , 0.9 EF, 120 mbtu/hr	ErRobNc	Res	unit	$733.10	4.01	$81.42	$326.70	$0.00	$1,059.80	$166.02							
Small Storage Gas WH (<= 75,000 BtuH and EF rated)	356, 377, 357, 378, 358, 379	Baseline	Small Gas Storage Water Heater 30 Gal, EF = 0.61, Recov Eff = 0.76	ErRobNc	Com/Res	unit	$685.74	3.89	$78.19	$304.10	$0.00	$989.84	-							
	356	Measure	Small Gas Storage Water Heater 30 Gal, EF = 0.62, Recov Eff = 0.77	ErRobNc	Com	unit	$712.56	3.89	$78.19	$304.10	$0.00	$1,016.66	$26.82							
	377	Measure	High Efficiency Small Gas Storage Water Heater - 30 Gal , 0.62 EF	ErRobNc	Res	unit	$712.56	3.89	$78.19	$304.10	$0.00	$1,016.66	$26.82							
	357	Measure	Small Gas Storage Water Heater 30 Gal, EF = 0.65, Recov Eff = 0.81	ErRobNc	Com	unit	$793.03	3.89	$78.19	$304.10	$0.00	$1,097.13	$107.30							
	378	Measure	High Efficiency Small Gas Storage Water Heater - 30 Gal , 0.65 EF	ErRobNc	Res	unit	$793.03	3.89	$78.19	$304.10	$0.00	$1,097.13	$107.30							
	358	Measure	Small Gas Storage Water Heater 30 Gal, EF = 0.70, Recov Eff = 0.81	ErRobNc	Com	unit	$927.15	3.89	$78.19	$304.10	$0.00	$1,231.25	$241.41							
	379	Measure	High Efficiency Small Gas Storage Water Heater - 30 Gal , 0.70 EF	ErRobNc	Res	unit	$927.15	3.89	$78.19	$304.10	$0.00	$1,231.25	$241.41							
	359, 380, 360, 381, 361, 382	Baseline	Small Gas Storage Water Heater 40 Gal, EF = 0.60, Recov Eff = 0.76	ErRobNc	Com/Res	unit	$763.19	4.20	$78.19	$328.73	$0.00	$1,091.92	-							
	359	Measure	Small Gas Storage Water Heater 40 Gal, EF = 0.62, Recov Eff = 0.77	ErRobNc	Com	unit	$816.84	4.20	$78.19	$328.73	$0.00	$1,145.57	$53.65							
	380	Measure	High Efficiency Small Gas Storage Water Heater - 40 Gal , 0.62 EF	ErRobNc	Res	unit	$816.84	4.20	$78.19	$328.73	$0.00	$1,145.57	$53.65							
	360	Measure	Small Gas Storage Water Heater 40 Gal, EF = 0.67, Recov Eff = 0.81	ErRobNc	Com	unit	$950.96	4.20	$78.19	$328.73	$0.00	$1,279.69	$187.77							
	381	Measure	High Efficiency Small Gas Storage Water Heater - 40 Gal , 0.67 EF	ErRobNc	Res	unit	$950.96	4.20	$78.19	$328.73	$0.00	$1,279.69	$187.77							
	361	Measure	Small Gas Storage Water Heater 40 Gal, EF = 0.70, Recov Eff = 0.81	ErRobNc	Com	unit	$1,031.43	4.20	$78.19	$328.73	$0.00	$1,360.16	$268.24							
	382	Measure	High Efficiency Small Gas Storage Water Heater - 40 Gal , 0.70 EF	ErRobNc	Res	unit	$1,031.43	4.20	$78.19	$328.73	$0.00	$1,360.16	$268.24							
	362, 383, 363, 384, 364, 385	Baseline	Small Gas Storage Water Heater 50 Gal, EF = 0.58, Recov Eff = 0.76	RobNc	Com/Res	unit	$813.82	4.52	$78.19	$353.36	$0.00	$1,167.18	-							
	362	Measure	Small Gas Storage Water Heater 50 Gal, EF = 0.62, Recov Eff = 0.77	RobNc	Com	unit	$921.12	4.52	$78.19	$353.36	$0.00	$1,274.47	$107.30							
	383	Measure	High Efficiency Small Gas Storage Water Heater - 50 Gal , 0.62 EF	RobNc	Res	unit	$921.12	4.52	$78.19	$353.36	$0.00	$1,274.47	$107.30							
	363	Measure	Small Gas Storage Water Heater 50 Gal, EF = 0.67, Recov Eff = 0.81	RobNc	Com	unit	$1,055.23	4.52	$78.19	$353.36	$0.00	$1,408.59	$241.41							
	384	Measure	High Efficiency Small Gas Storage Water Heater - 50 Gal , 0.67 EF	RobNc	Res	unit	$1,055.23	4.52	$78.19	$353.36	$0.00	$1,408.59	$241.41							
	364	Measure	Small Gas Storage Water Heater 50 Gal, EF = 0.70, Recov Eff = 0.81	RobNc	Com	unit	$1,135.71	4.52	$78.19	$353.36	$0.00	$1,489.07	$321.89							
	385	Measure	High Efficiency Small Gas Storage Water Heater - 50 Gal , 0.70 EF	RobNc	Res	unit	$1,135.71	4.52	$78.19	$353.36	$0.00	$1,489.07	$321.89							
	365, 386, 366, 387, 367, 388	Baseline	Small Gas Storage Water Heater 60 Gal, EF = 0.56, Recov Eff = 0.76	RobNc	Com/Res	unit	$864.45	4.83	$78.19	$377.99	$0.00	$1,242.44	-							
	365	Measure	Small Gas Storage Water Heater 60 Gal, EF = 0.62, Recov Eff = 0.76	RobNc	Com	unit	$1,025.39	4.83	$78.19	$377.99	$0.00	$1,403.38	$160.94							
	386	Measure	High Efficiency Small Gas Storage Water Heater - 60 Gal , 0.62 EF	RobNc	Res	unit	$1,025.39	4.83	$78.19	$377.99	$0.00	$1,403.38	$160.94							
	366	Measure	Small Gas Storage Water Heater 60 Gal, EF = 0.66, Recov Eff = 0.81	RobNc	Com	unit	$1,132.69	4.83	$78.19	$377.99	$0.00	$1,510.68	$268.24							
	387	Measure	High Efficiency Small Gas Storage Water Heater - 60 Gal , 0.66 EF	RobNc	Res	unit	$1,132.69	4.83	$78.19	$377.99	$0.00	$1,510.68	$268.24							
	367	Measure	Small Gas Storage Water Heater 60 Gal, EF = 0.70, Recov Eff = 0.81	RobNc	Com	unit	$1,239.98	4.83	$78.19	$377.99	$0.00	$1,617.97	$375.53							
	388	Measure	High Efficiency Small Gas Storage Water Heater - 60 Gal , 0.70 EF	RobNc	Res	unit	$1,239.98	4.83	$78.19	$377.99	$0.00	$1,617.97	$375.53							
	368, 389, 369, 390, 370, 391	Baseline	Small Gas Storage Water Heater 75 Gal, EF = 0.53, Recov Eff = 0.76	ErRobNc	Com/Res	unit	$940.40	5.31	$78.19	$414.93	$0.00	$1,355.33	-							
	368	Measure	Small Gas Storage Water Heater 75 Gal, EF = 0.62, Recov Eff = 0.80	ErRobNc	Com	unit	$1,181.81	5.31	$78.19	$414.93	$0.00	$1,596.74	$241.41							
	389	Measure	High Efficiency Small Gas Storage Water Heater - 75 Gal , 0.62 EF	ErRobNc	Res	unit	$1,181.81	5.31	$78.19	$414.93	$0.00	$1,596.74	$241.41							
	369	Measure	Small Gas Storage Water Heater 75 Gal, EF = 0.66, Recov Eff = 0.81	ErRobNc	Com	unit	$1,289.11	5.31	$78.19	$414.93	$0.00	$1,704.04	$348.71							
	390	Measure	High Efficiency Small Gas Storage Water Heater - 75 Gal , 0.66 EF	ErRobNc	Res	unit	$1,289.11	5.31	$78.19	$414.93	$0.00	$1,704.04	$348.71							
	370	Measure	Small Gas Storage Water Heater 75 Gal, EF = 0.70, Recov Eff = 0.81	ErRobNc	Com	unit	$1,396.40	5.31	$78.19	$414.93	$0.00	$1,811.33	$456.00							
	391	Measure	High Efficiency Small Gas Storage Water Heater - 75 Gal , 0.70 EF	ErRobNc	Res	unit	$1,396.40	5.31	$78.19	$414.93	$0.00	$1,811.33	$456.00							

Technology	READI Index ID	Match Pair	Description	Measure Type	Sector	Unit	Equipment Cost	Labor Hours	CA Average Labor Rate	Labor Cost	Misc. Costs	Full Installed Cost	Incremental Cost	Equipment Cost per unit	Labor Cost per Unit	Misc. Costs Per Unit	Misc. Fixed Costs per Project	Full Cost per Unit	Incremental Cost per Unit	Incremental Fixed Cost per Project
	Measure Information						**Total Costs**							**Per Unit Costs**						
Electric Storage WH	344	Measure	Large Electric Storage Water Heater, Recov Eff = 0.98, Stdby Loss = 0.27%/hr gt12kW out of sample	RobNc	Com	unit														
	351, 371	Baseline	Small Electric Storage Water Heater 30 Gal, EF = 0.93, Recov Eff = 0.98 lte 12kW	RobNc	Com/Res	unit	$361.48	3.72	$79.48	$295.47	$0.00	$656.95	-							
	351	Measure	Small Electric Storage Water Heater 30 Gal, EF = 0.95, Recov Eff = 0.98 lte 12kW	RobNc	Com	unit	$566.57	3.72	$79.48	$295.47	$0.00	$862.04	$205.09							
	371	Measure	High Efficiency Small Electric Storage Water Heater - 30 Gal , 0.95 EF lte 12kW	RobNc	Res	unit	$566.57	3.72	$79.48	$295.47	$0.00	$862.04	$205.09							
	352, 372	Baseline	Small Electric Storage Water Heater 40 Gal, EF = 0.92, Recov Eff = 0.98 lte 12kW	RobNc	Com/Res	unit	$420.93	3.94	$79.48	$313.12	$0.00	$734.04	-							
	352	Measure	Small Electric Storage Water Heater 40 Gal, EF = 0.94, Recov Eff = 0.98 lte 12kW	RobNc	Com	unit	$626.01	3.94	$79.48	$313.12	$0.00	$939.13	$205.09							
	372	Measure	High Efficiency Small Electric Storage Water Heater - 40 Gal , 0.94 EF lte 12kW	RobNc	Res	unit	$626.01	3.94	$79.48	$313.12	$0.00	$939.13	$205.09							
	353, 373	Baseline	Small Electric Storage Water Heater 50 Gal, EF = 0.90, Recov Eff = 0.98 lte 12kW	RobNc	Com/Res	unit	$377.83	4.16	$79.48	$330.76	$0.00	$708.59	-							
	353	Measure	Small Electric Storage Water Heater 50 Gal, EF = 0.93, Recov Eff = 0.98 lte 12kW	RobNc	Com	unit	$685.46	4.16	$79.48	$330.76	$0.00	$1,016.22	$307.63							
	373	Measure	High Efficiency Small Electric Storage Water Heater - 50 Gal , 0.93 EF lte 12kW	RobNc	Res	unit	$685.46	4.16	$79.48	$330.76	$0.00	$1,016.22	$307.63							
	354, 374	Baseline	Small Electric Storage Water Heater 60 Gal, EF = 0.89, Recov Eff = 0.98 lte 12kW	RobNc	Com/Res	unit	$437.27	4.38	$79.48	$348.41	$0.00	$785.68	-							
	354	Measure	Small Electric Storage Water Heater 60 Gal, EF = 0.92, Recov Eff = 0.98 lte 12kW	RobNc	Com	unit	$744.90	4.38	$79.48	$348.41	$0.00	$1,093.31	$307.63							
	374	Measure	High Efficiency Small Electric Storage Water Heater - 60 Gal , 0.92 EF lte 12kW	RobNc	Res	unit	$744.90	4.38	$79.48	$348.41	$0.00	$1,093.31	$307.63							
	355, 375	Baseline	Small Electric Storage Water Heater 75 Gal, EF = 0.87, Recov Eff = 0.98 lte 12kW	RobNc	Com/Res	unit	$475.17	4.72	$79.48	$374.87	$0.00	$850.04	-							
	355	Measure	Small Electric Storage Water Heater 75 Gal, EF = 0.91, Recov Eff = 0.98 lte 12kW	RobNc	Com	unit	$885.34	4.72	$79.48	$374.87	$0.00	$1,260.22	$410.17							
	375	Measure	High Efficiency Small Electric Storage Water Heater - 75 Gal , 0.91 EF lte 12kW	RobNc	Res	unit	$885.34	4.72	$79.48	$374.87	$0.00	$1,260.22	$410.17							
Heat Pump Water Heaters	Example Measures	Baseline	Small Electric Storage Water Heater 40 Gal; EF = 0.92; Recov Eff = 0.98	RobNc	Res	unit	$420.93	3.94	$79.48	$313.12	$0.00	$734.04	-							
		Measure	Heat pump water heater, 40 gallons, 4.0 kw, 2.0 EF, 240 volt	RobNc	Res	unit	$1,761.23	7.95	$58.83	$467.69	$0.00	$2,228.92	$1,494.88							
		Baseline	Small Electric Storage Water Heater 50 Gal, EF = 0.90, Recov Eff = 0.98 lte 12kW	RobNc	Com/Res	unit	$377.83	4.16	$79.48	$330.76	$0.00	$708.59	-							
		Measure	Heat pump water heater, 50 gallons, 4.5 kw, 2.4 EF, 240 volt	RobNc	Res	unit	$1,565.41	7.95	$58.83	$467.69	$0.00	$2,033.09	$1,324.50							
		Measure	Heat pump water heater, 50 gallons, 5.5 kw, 2.45 EF, 230 volt	RobNc	Res	unit	$1,295.82	7.95	$58.83	$467.69	$0.00	$1,763.50	$1,054.91							
		Baseline	Small Electric Storage Water Heater 60 Gal, EF = 0.89, Recov Eff = 0.98 lte 12kW	RobNc	Com/Res	unit	$437.27	4.38	$79.48	$348.41	$0.00	$785.68	-							
		Measure	Heat pump water heater, 60 gallons, 4.5 kw, 2.33 EF, 240 volt	RobNc	Res	unit	$1,852.46	7.95	$58.83	$467.69	$0.00	$2,320.15	$1,534.47							
Non-Residential Water Heating																				
Large Storage Gas WH (> 75,000 BtuH and TE rated)	392, 393	Baseline	Large Gas Storage Water Heater, Et = 0.80, Stdby Loss = 0.56%/hr gte75kBtuh assumed 75 gal capacity and 125 MBH	ErRobNc	Com	MBH	$4,713.93	7.80	$74.31	$579.68	$0.00	$5,293.61	-	$37.71	$4.64	$0.00		$42.35	-	
	392	Measure	Large Gas Storage Water Heater, Et = 0.83, Stdby Loss = 0.56%/hr gte75kBtuh assumed 75 gal capacity and 125 MBH	ErRobNc	Com	MBH	$5,105.96	7.80	$74.31	$579.68	$0.00	$5,685.63	$392.02	$40.85	$4.64	$0.00		$45.49	$3.14	
	393	Measure	Large Gas Storage Water Heater, Et = 0.90, Stdby Loss = 0.56%/hr gte75kBtuh assumed 75 gal capacity and 125 MBH	ErRobNc	Com	MBH	$6,020.67	7.80	$74.31	$579.68	$0.00	$6,600.35	$1,306.74	$48.17	$4.64	$0.00		$52.80	$10.45	
	100110	Baseline	Standard Efficiency Central Storage WH, Et =80%, 80 Gallons assumed 175 MBH	RobNc	Res	MBH	$5,535.17	11.08	$74.31	$823.05	$0.00	$6,358.21	-	$31.63	$4.70	$0.00		$36.33	-	
	100110	Measure	MFm Central Storage Water heater, Et =83%, 80 Gallons assumed 175 MBH	RobNc	Res	MBH	$5,927.19	11.08	$74.31	$823.05	$0.00	$6,750.23	$392.02	$33.87	$4.70	$0.00		$38.57	$2.24	
SHW Boilers (< 300 kBtuh, non-condensing)	161, 162, 100097, 100111, 100114	Baseline	Hot water boiler (<300 kBtuh, 82.0% AFUE, atmospheric) assumed 250 MBH ground mount	RobNc	Com	MBH	$2,574.40	34.84	$79.64	$2,774.52	$10,842.28	$16,191.19	-	$10.30	$11.10	$36.61	$1,689.38	$58.01	-	-
	161, 100097, 100111, 100114	Measure	Hot water boiler (< 300 kBTUh, 84.5% AFUE, atmospheric) assumed 250 MBH ground mount	RobNc	Com	MBH	$6,187.55	34.84	$79.64	$2,774.52	$10,842.28	$19,804.35	$3,613.15	$24.75	$11.10	$36.61	$1,689.38	$72.46	$14.45	$0.00
	162	Measure	Hot water boiler (< 300 kBTUh, 84.5% AFUE, forced draft) assumed 250 MBH ground mount	RobNc	Com	MBH	$6,187.55	34.84	$79.64	$2,774.52	$10,842.28	$19,804.35	$3,613.15	$24.75	$11.10	$36.61	$1,689.38	$72.46	$14.45	$0.00
SHW Boilers (> 300 kBtuh, non-condensing)	164, 165, 100093, 100112	Baseline	Hot water boiler (300-2500 kBtuh, 82.0% thermal efficiency, atmospheric) assumed 1400 MBH basement mount	RobNc	Com	MBH	$17,640.70	97.11	$79.64	$7,733.87	$27,618.92	$52,993.50	-	$12.60	$5.52	$16.59	$4,398.75	$34.71	-	-
	164, 100093, 100112	Measure	Hot water boiler (300-2500 kBTUh, 85.0% thermal efficiency, atmospheric) assumed 1400 MBH basement mount	RobNc	Com	MBH	$37,354.94	97.11	$79.64	$7,733.87	$27,618.92	$72,707.73	$19,714.23	$26.68	$5.52	$16.59	$4,398.75	$48.79	$14.08	$0.00
	165	Measure	Hot water boiler (300-2500 kBTUh, 85.0% thermal efficiency, forced draft) assumed 1400 MBH basement mount	RobNc	Com	MBH	$37,354.94	97.11	$79.64	$7,733.87	$27,618.92	$72,707.73	$19,714.23	$26.68	$5.52	$16.59	$4,398.75	$48.79	$14.08	$0.00
	167, 168	Baseline	Hot water boiler (> 2500 kBtuh, 82.0% combustion efficiency, atmospheric) assumed 3000 MBH roof mount	RobNc	Com	MBH	$45,794.13	172.31	$79.64	$13,723.01	$37,859.85	$97,376.99	-	$15.26	$4.57	$10.55	$6,215.63	$30.39	-	-
	167	Measure	Hot water boiler (> 2500 kBTUh, 85.0% combustion efficiency, atmospheric) assumed 3000 MBH roof mount	RobNc	Com	MBH	$65,508.36	172.31	$79.64	$13,723.01	$37,859.85	$117,091.22	$19,714.23	$21.84	$4.57	$10.55	$6,215.63	$36.96	$6.57	$0.00
	168	Measure	Hot water boiler (> 2500 kBTUh, 85.0% combustion efficiency, forced draft) assumed 3000 MBH roof mount	RobNc	Com	MBH	$65,508.36	172.31	$79.64	$13,723.01	$37,859.85	$117,091.22	$19,714.23	$21.84	$4.57	$10.55	$6,215.63	$36.96	$6.57	$0.00

	Measure Information						Total Costs							Per Unit Costs						
Technology	READI Index ID	Match Pair	Description	Measure Type	Sector	Unit	Equipment Cost	Labor Hours	CA Average Labor Rate	Labor Cost	Misc. Costs	Full Installed Cost	Incremental Cost	Equipment Cost per unit	Labor Cost per Unit	Misc. Costs Per Unit	Misc. Fixed Costs per Project	Full Cost per Unit	Incremental Cost per Unit	Incremental Fixed Cost per Project
SHW Boilers (condensing)	163	Baseline	Hot water boiler (<300 kBtuh, 82.0% AFUE, atmospheric) assumed 250 MBH ground mount	RobNc	Com	MBH	$2,574.40	34.84	$79.64	$2,774.52	$10,842.28	$16,191.19	-	$10.30	$11.10	$36.61	$1,689.38	$58.01	-	-
	163	Measure	Hot water boiler (< 300 kBTUh, 94.0 AFUE, condensing) assumed 250 MBH ground mount	RobNc	Com	MBH	$10,075.14	23.20	$76.47	$1,773.95	$10,842.28	$22,691.37	$6,500.18	$40.30	$7.10	36.611625	1689.375	$84.01	$26.00	$0.00
	166	Baseline	Hot water boiler (300-2500 kBtuh, 82.0% thermal efficiency, atmospheric) assumed 1400 MBH basement mount	RobNc	Com	MBH	$17,640.70	97.11	$79.64	$7,733.87	$27,618.92	$52,993.50	-	$12.60	$5.52	$16.59	$4,398.75	$34.71	-	-
	166	Measure	Hot water boiler (300-2500 kBTUh, 94.0% thermal efficiency, condensing) assumed 1400 MBH basement mount	RobNc	Com	MBH	$24,823.91	103.70	$76.47	$7,929.65	$27,618.92	$60,372.48	$7,378.98	$17.73	$5.66	16.5858375	4398.75	$39.98	$5.27	$0.00
Lighting - MSB Lamps																				
CFL A-Lamps and Twisters	201, 2225	Baseline	Incandescent A-lamp 350 W out of sample	ErRobNc	Res/Com	lamp														
	201	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-100w out of sample	ErRobNc	Res	lamp														
	2225	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-100w out of sample	ErRobNc	Com	lamp														
	234, 236, 237, 202, 203, 2194 - 2198	Baseline	Assumed Incandescent A-lamp 29 W EISA 1500 hrs low brightness	ErRobNc	Res/Com	lamp	$1.14	0.08	$72.26	$5.75	$0.00	$6.89	-							
	234	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-7w low brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$2.66	0.08	$72.26	$5.75	$0.00	$8.41	$1.52							
	236	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-8w low brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$2.72	0.08	$72.26	$5.75	$0.00	$8.48	$1.59							
	237	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-9w low brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$2.79	0.08	$72.26	$5.75	$0.00	$8.54	$1.65							
	202	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-10w low brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$2.86	0.08	$72.26	$5.75	$0.00	$8.61	$1.72							
	203	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-11w low brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$2.92	0.08	$72.26	$5.75	$0.00	$8.68	$1.79							
	2194	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-7w low brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$2.66	0.08	$72.26	$5.75	$0.00	$8.41	$1.52							
	2195	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-8w low brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$2.72	0.08	$72.26	$5.75	$0.00	$8.48	$1.59							
	2196	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-9w low brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$2.79	0.08	$72.26	$5.75	$0.00	$8.54	$1.65							
	2197	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-10w low brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$2.86	0.08	$72.26	$5.75	$0.00	$8.61	$1.72							
	2198	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-11w low brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$2.92	0.08	$72.26	$5.75	$0.00	$8.68	$1.79							
	204, 205, 2199, 2200	Baseline	Assumed Incandescent A-lamp 45 W EISA 1500 hrs med brightness	ErRobNc	Res/Com	lamp	$1.27	0.08	$72.26	$5.75	$0.00	$7.03	-							
	204	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-12w med brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$2.99	0.08	$72.26	$5.75	$0.00	$8.74	$1.71							
	205	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-13w med brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$3.06	0.08	$72.26	$5.75	$0.00	$8.81	$1.78							
	2199	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-12w med brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$2.99	0.08	$72.26	$5.75	$0.00	$8.74	$1.71							
	2200	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-13w med brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$3.06	0.08	$72.26	$5.75	$0.00	$8.81	$1.78							
	206, 208, 2201, 2202	Baseline	Assumed Incandescent A-lamp 55 W EISA 1500 hrs med brightness	ErRobNc	Res/Com	lamp	$1.37	0.08	$72.26	$5.75	$0.00	$7.12	-							
	206	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-14w med brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$3.12	0.08	$72.26	$5.75	$0.00	$8.88	$1.76							
	208	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-15w med brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$3.19	0.08	$72.26	$5.75	$0.00	$8.94	$1.82							
	2201	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-14w med brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$3.12	0.08	$72.26	$5.75	$0.00	$8.88	$1.76							
	2202	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-15w med brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$3.19	0.08	$72.26	$5.75	$0.00	$8.94	$1.82							
	209, 210, 2203, 2204	Baseline	Assumed Incandescent A-lamp 65 W EISA 1500 hrs med brightness	ErRobNc	Res/Com	lamp	$1.46	0.08	$72.26	$5.75	$0.00	$7.21	-							
	209	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-16w med brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$3.26	0.08	$72.26	$5.75	$0.00	$9.01	$1.80							
	210	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-17w med brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$3.32	0.08	$72.26	$5.75	$0.00	$9.08	$1.86							
	2203	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-16w med brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$3.26	0.08	$72.26	$5.75	$0.00	$9.01	$1.80							
	2204	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-17w med brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$3.32	0.08	$72.26	$5.75	$0.00	$9.08	$1.86							
	211, 212, 214, 215, 216, 2205 - 2209	Baseline	Assumed Incandescent A-lamp 70 W EISA 1500 hrs med brightness	ErRobNc	Res/Com	lamp	$1.50	0.08	$72.26	$5.75	$0.00	$7.26	-							
	211	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-18w high brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$3.39	0.08	$72.26	$5.75	$0.00	$9.14	$1.88							
	212	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-19w high brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$3.45	0.08	$72.26	$5.75	$0.00	$9.21	$1.95							
	214	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-20w high brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$3.52	0.08	$72.26	$5.75	$0.00	$9.28	$2.02							
	215	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-21w high brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$3.59	0.08	$72.26	$5.75	$0.00	$9.34	$2.08							
	216	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-22w high brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$3.65	0.08	$72.26	$5.75	$0.00	$9.41	$2.15							
	2205	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-18w high brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$3.39	0.08	$72.26	$5.75	$0.00	$9.14	$1.88							
	2206	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-19w high brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$3.45	0.08	$72.26	$5.75	$0.00	$9.21	$1.95							

	Measure Information						Total Costs							Per Unit Costs						
Technology	READI Index ID	Match Pair	Description	Measure Type	Sector	Unit	Equipment Cost	Labor Hours	CA Average Labor Rate	Labor Cost	Misc. Costs	Full Installed Cost	Incremental Cost	Equipment Cost per unit	Labor Cost per Unit	Misc. Costs Per Unit	Misc. Fixed Costs per Project	Full Cost per Unit	Incremental Cost per Unit	Incremental Fixed Cost per Project
	2207	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-20w high brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$3.52	0.08	$72.26	$5.75	$0.00	$9.28	$2.02							
	2208	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-21w high brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$3.59	0.08	$72.26	$5.75	$0.00	$9.34	$2.08							
	2209	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-22w high brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$3.65	0.08	$72.26	$5.75	$0.00	$9.41	$2.15							
	217 - 224, 2210 - 2217	Baseline	Assumed Incandescent A-lamp 72 W EISA 1500 hrs high brightness	ErRobNc	Res/Com	lamp	$1.52	0.08	$72.26	$5.75	$0.00	$7.28	-							
	217	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-23w high brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$3.72	0.08	$72.26	$5.75	$0.00	$9.47	$2.20							
	218	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-24w high brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$3.79	0.08	$72.26	$5.75	$0.00	$9.54	$2.26							
	219	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-25w high brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$3.85	0.08	$72.26	$5.75	$0.00	$9.61	$2.33							
	220	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-26w high brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$6.35	0.08	$72.26	$5.75	$0.00	$12.11	$4.83							
	221	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-27w high brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$6.51	0.08	$72.26	$5.75	$0.00	$12.27	$4.99							
	222	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-28w high brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$6.67	0.08	$72.26	$5.75	$0.00	$12.43	$5.15							
	223	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-29w high brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$6.83	0.08	$72.26	$5.75	$0.00	$12.59	$5.31							
	224	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-30w high brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$6.99	0.08	$72.26	$5.75	$0.00	$12.75	$5.47							
	2210	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-23w high brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$3.72	0.08	$72.26	$5.75	$0.00	$9.47	$2.20							
	2211	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-24w high brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$3.79	0.08	$72.26	$5.75	$0.00	$9.54	$2.26							
	2212	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-25w high brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$3.85	0.08	$72.26	$5.75	$0.00	$9.61	$2.33							
	2213	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-26w high brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$6.35	0.08	$72.26	$5.75	$0.00	$12.11	$4.83							
	2214	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-27w high brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$6.51	0.08	$72.26	$5.75	$0.00	$12.27	$4.99							
	2215	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-28w high brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$6.67	0.08	$72.26	$5.75	$0.00	$12.43	$5.15							
	2216	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-29w high brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$6.83	0.08	$72.26	$5.75	$0.00	$12.59	$5.31							
CFL A-Lamps and Twisters	2217	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-30w high brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$6.99	0.08	$72.26	$5.75	$0.00	$12.75	$5.47							
	225, 226, 228, 2218 - 2221	Baseline	Assumed Incandescent A-lamp 175 W 1500 hrs very high brightness (out of sample)	ErRobNc	Res/Com	lamp	$1.26	0.08	$72.26	$5.75	$0.00	$7.01	-							
	225	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-31w very high brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$7.15	0.08	$72.26	$5.75	$0.00	$12.91	$5.89							
	226	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-32w very high brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$7.31	0.08	$72.26	$5.75	$0.00	$13.07	$6.05							
	228	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-42w very high brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$8.91	0.08	$72.26	$5.75	$0.00	$14.67	$7.65							
	2218	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-31w very high brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$7.15	0.08	$72.26	$5.75	$0.00	$12.91	$5.89							
	2219	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-32w very high brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$7.31	0.08	$72.26	$5.75	$0.00	$13.07	$6.05							
	2220	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-40w very high brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$8.59	0.08	$72.26	$5.75	$0.00	$14.35	$7.33							
	2221	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-42w very high brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$8.91	0.08	$72.26	$5.75	$0.00	$14.67	$7.65							
	227, 229, 231, 233, 2190 - 2193	Baseline	Assumed Incandescent A-lamp 25 W 1500 hrs low brightness	ErRobNc	Res/Com	lamp	$0.80	0.08	$72.26	$5.75	$0.00	$6.56	-							
	227	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-3w low brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$2.39	0.08	$72.26	$5.75	$0.00	$8.14	$1.59							
	229	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-4w low brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$2.46	0.08	$72.26	$5.75	$0.00	$8.21	$1.65							
	231	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-5w low brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$2.52	0.08	$72.26	$5.75	$0.00	$8.28	$1.72							
	233	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-6w low brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$2.59	0.08	$72.26	$5.75	$0.00	$8.34	$1.79							
	2190	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-3w low brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$2.39	0.08	$72.26	$5.75	$0.00	$8.14	$1.59							
	2191	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-4w low brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$2.46	0.08	$72.26	$5.75	$0.00	$8.21	$1.65							
	2192	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-5w low brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$2.52	0.08	$72.26	$5.75	$0.00	$8.28	$1.72							

	Measure Information						Total Costs							Per Unit Costs						
Technology	READI Index ID	Match Pair	Description	Measure Type	Sector	Unit	Equipment Cost	Labor Hours	CA Average Labor Rate	Labor Cost	Misc. Costs	Full Installed Cost	Incremental Cost	Equipment Cost per unit	Labor Cost per Unit	Misc. Costs Per Unit	Misc. Fixed Costs per Project	Full Cost per Unit	Incremental Cost per Unit	Incremental Fixed Cost per Project
CFL A-Lamps and Twisters	2193	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-6w low brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$2.59	0.08	$72.26	$5.75	$0.00	$8.34	$1.79							
	230, 232, 2222, 2223	Baseline	Assumed Incandescent A-lamp 250 W 1500 hrs very high brightness (out of sample)	ErRobNc	Res/Com	lamp	$1.29	0.08	$72.26	$5.75	$0.00	$7.04	-							
	230	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-55w very high brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$10.99	0.08	$72.26	$5.75	$0.00	$16.75	$9.70							
	232	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-60w very high brightness 10,000 hrs twister non-dim	ErRobNc	Res	lamp	$11.79	0.08	$72.26	$5.75	$0.00	$17.55	$10.50							
	2222	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-55w very high brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$10.99	0.08	$72.26	$5.75	$0.00	$16.75	$9.70							
	2223	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-60w very high brightness 10,000 hrs twister non-dim	ErRobNc	Com	lamp	$11.79	0.08	$72.26	$5.75	$0.00	$17.55	$10.50							
	235, 2224	Baseline	Incandescent A-lamp out of sample wattage too high	ErRobNc	Res/Com	lamp														
	235	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-80w out of sample	ErRobNc	Res	lamp														
	2224	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-80w out of sample	ErRobNc	Com	lamp														
	213, 2227	Baseline	Incandescent A-lamp out of sample wattage too high	ErRobNc	Res/Com	lamp														
	213	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-200w out of sample	ErRobNc	Res	lamp														
	2227	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-200w out of sample	ErRobNc	Com	lamp														
	207, 2226	Baseline	Incandescent A-lamp out of sample wattage too high	ErRobNc	Res/Com	lamp														
	207	Measure	Res, Res indoor non-refl CFL base case, Total Watts = 3.47 x Msr Watts ==> CFLscw-150w out of sample	ErRobNc	Res	lamp														
	2226	Measure	Com, Com indoor non-refl CFL base case, Total Watts = 3.57 x Msr Watts ==> CFLscw-150w out of sample	ErRobNc	Com	lamp														
CFL Reflectors	264, 266, 268	Baseline	Assumed Incandescent Reflector 15 W 2000 hrs low brightness				$5.69	0.06	$72.26	$4.48	$0.00	$10.17	-							
	264	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-3w low brightness, non-dimmable	ErRobNc	Res	lamp	$6.07	0.06	$72.26	$4.48	$0.00	$10.55	$0.38							
	266	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-4w low brightness, non-dimmable	ErRobNc	Res	lamp	$6.21	0.06	$72.26	$4.48	$0.00	$10.70	$0.52							
	268	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-5w low brightness, non-dimmable	ErRobNc	Res	lamp	$6.36	0.06	$72.26	$4.48	$0.00	$10.84	$0.67							
	270, 271, 273, 274	Baseline	Assumed Incandescent Reflector 30 W 2000 hrs low brightness	ErRobNc	Res	lamp	$5.85	0.06	$72.26	$4.48	$0.00	$10.33	-							
	270	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-6w low brightness, non-dimmable	ErRobNc	Res	lamp	$6.51	0.06	$72.26	$4.48	$0.00	$10.99	$0.66							
	271	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-7w low brightness, non-dimmable	ErRobNc	Res	lamp	$6.66	0.06	$72.26	$4.48	$0.00	$11.14	$0.81							
	273	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-8w low brightness, non-dimmable	ErRobNc	Res	lamp	$6.80	0.06	$72.26	$4.48	$0.00	$11.28	$0.96							
	274	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-9w low brightness, non-dimmable	ErRobNc	Res	lamp	$6.95	0.06	$72.26	$4.48	$0.00	$11.43	$1.10							
	239, 240, 241, 242	Baseline	Assumed Incandescent Reflector 45 W 2000 hrs low brightness	ErRobNc	Res	lamp	$6.00	0.06	$72.26	$4.48	$0.00	$10.48	-							
	239	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-10w low brightness, non-dimmable	ErRobNc	Res	lamp	$7.10	0.06	$72.26	$4.48	$0.00	$11.58	$1.10							
	240	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-11w low brightness, non-dimmable	ErRobNc	Res	lamp	$7.25	0.06	$72.26	$4.48	$0.00	$11.73	$1.24							
	241	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-12w low brightness, non-dimmable	ErRobNc	Res	lamp	$7.39	0.06	$72.26	$4.48	$0.00	$11.87	$1.39							
	242	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-13w low brightness, non-dimmable	ErRobNc	Res	lamp	$7.54	0.06	$72.26	$4.48	$0.00	$12.02	$1.54							
	243, 245, 246	Baseline	Assumed Incandescent Reflector 60 W 2000 hrs med brightness	ErRobNc	Res	lamp	$6.16	0.06	$72.26	$4.48	$0.00	$10.64	-							
	243	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-14w med brightness, non-dimmable	ErRobNc	Res	lamp	$7.69	0.06	$72.26	$4.48	$0.00	$12.17	$1.53							
	245	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-15w med brightness, non-dimmable	ErRobNc	Res	lamp	$7.84	0.06	$72.26	$4.48	$0.00	$12.32	$1.68							
	246	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-16w med brightness, non-dimmable	ErRobNc	Res	lamp	$7.98	0.06	$72.26	$4.48	$0.00	$12.46	$1.82							
	247, 248, 249	Baseline	Assumed Incandescent Reflector 75 W 2000 hrs med brightness	ErRobNc	Res	lamp	$6.31	0.06	$72.26	$4.48	$0.00	$10.79	-							
	247	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-17w med brightness, non-dimmable	ErRobNc	Res	lamp	$8.13	0.06	$72.26	$4.48	$0.00	$12.61	$1.81							
	248	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-18w med brightness, non-dimmable	ErRobNc	Res	lamp	$8.28	0.06	$72.26	$4.48	$0.00	$12.76	$1.96							
	249	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-19w med brightness, non-dimmable	ErRobNc	Res	lamp	$8.42	0.06	$72.26	$4.48	$0.00	$12.90	$2.11							
	251, 252, 253, 254, 255, 256	Baseline	Assumed Incandescent Reflector 90 W 2000 hrs high brightness	ErRobNc	Res	lamp	$6.47	0.06	$72.26	$4.48	$0.00	$10.95	-							
	251	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-20w high brightness, non-dimmable	ErRobNc	Res	lamp	$8.57	0.06	$72.26	$4.48	$0.00	$13.05	$2.10							
	252	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-21w high brightness, non-dimmable	ErRobNc	Res	lamp	$8.72	0.06	$72.26	$4.48	$0.00	$13.20	$2.25							
	253	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-22w high brightness, non-dimmable	ErRobNc	Res	lamp	$8.87	0.06	$72.26	$4.48	$0.00	$13.35	$2.40							

	Measure Information						Total Costs							Per Unit Costs						
Technology	READI Index ID	Match Pair	Description	Measure Type	Sector	Unit	Equipment Cost	Labor Hours	CA Average Labor Rate	Labor Cost	Misc. Costs	Full Installed Cost	Incremental Cost	Equipment Cost per unit	Labor Cost per Unit	Misc. Costs Per Unit	Misc. Fixed Costs per Project	Full Cost per Unit	Incremental Cost per Unit	Incremental Fixed Cost per Project
CFL Reflectors	254	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-23w high brightness, non-dimmable	ErRobNc	Res	lamp	$9.01	0.06	$72.26	$4.48	$0.00	$13.49	$2.54							
	255	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-24w high brightness, non-dimmable	ErRobNc	Res	lamp	$9.16	0.06	$72.26	$4.48	$0.00	$13.64	$2.69							
	256	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-25w high brightness, non-dimmablehigh brightness, non-dimmable	ErRobNc	Res	lamp	$9.31	0.06	$72.26	$4.48	$0.00	$13.79	$2.84							
	257, 258, 259, 260, 261	Baseline	Assumed Incandescent Reflector 120 W 2000 hrs high brightness	ErRobNc	Res	lamp	$6.78	0.06	$72.26	$4.48	$0.00	$11.26	-							
	257	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-26w high brightness, non-dimmable	ErRobNc	Res	lamp	$9.46	0.06	$72.26	$4.48	$0.00	$13.94	$2.67							
	258	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-27w high brightness, non-dimmable	ErRobNc	Res	lamp	$9.60	0.06	$72.26	$4.48	$0.00	$14.08	$2.82							
	259	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-28w high brightness, non-dimmable	ErRobNc	Res	lamp	$9.75	0.06	$72.26	$4.48	$0.00	$14.23	$2.97							
	260	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-29w high brightness, non-dimmable	ErRobNc	Res	lamp	$9.90	0.06	$72.26	$4.48	$0.00	$14.38	$3.11							
	261	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-30w high brightness, non-dimmable	ErRobNc	Res	lamp	$10.04	0.06	$72.26	$4.48	$0.00	$14.52	$3.26							
	262	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-31w out of sample	ErRobNc	Res	lamp														
	263	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-32w out of sample	ErRobNc	Res	lamp														
	265	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-42w out of sample	ErRobNc	Res	lamp														
	267	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-55w out of sample	ErRobNc	Res	lamp														
	269	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-60w out of sample	ErRobNc	Res	lamp														
	272	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-80w out of sample	ErRobNc	Res	lamp														
	238	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-100w out of sample	ErRobNc	Res	lamp														
	244	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-150w out of sample	ErRobNc	Res	lamp														
	250	Measure	Res, Res indoor Reflector CFL base case, Total Watts = 4.09 x Msr Watts ==> CFLscw-Refl-200w out of sample	ErRobNc	Res	lamp														
CFL Globe	Example Measures	Baseline	Incandescent Globe, 2,000 hours, low brightness (40 watts)	ErRobNc	Res	lamp	$4.75	0.05	$72.26	$3.61	$0.00	$8.37	-							
		Measure	CFL Globe (10 watts)	ErRobNc	Res	lamp	$7.36	0.05	$72.26	$3.61	$0.00	$10.97	$2.60							
		Baseline	Incandescent Globe, 2,000 hours, medium brightness (60 watts)	ErRobNc	Res	lamp	$4.94	0.05	$72.26	$3.61	$0.00	$8.55	-							
		Measure	CFL Globe (15 watts)	ErRobNc	Res	lamp	$7.23	0.05	$72.26	$3.61	$0.00	$10.84	$2.29							
CFL Torpedo	Example Measures	Baseline	Incandscent Torpedo, 2,000 hours	ErRobNc	Res	lamp	$2.05	0.08	$72.26	$5.75	$0.00	$7.81	-							
		Measure	CFL Torpedo, 10,000 hours, low brightness (11 watts)	ErRobNc	Res	lamp	$8.24	0.08	$72.26	$5.75	$0.00	$14.00	$6.19							
		Measure	CFL Torpedo, 10,000 hours, medium brightness (15 watts)	ErRobNc	Res	lamp	$9.07	0.08	$72.26	$5.75	$0.00	$14.82	$7.01							
LED A-Lamp	Example Measures	Baseline	Incandescent A-Lamp, EISA, 1,500 hours, low brightness (40 watts)	ErRobNc	Res	lamp	$1.23	0.08	$72.26	$5.75	$0.00	$6.98	-							
		Measure	LED A-Lamp, Energy Star, low brightness (9 watts)	ErRobNc	Res	lamp	$28.29	0.08	$72.26	$5.75	$0.00	$34.05	$27.07							
		Baseline	CFL Twister, 10,000 hours, low brightness (10 watts)	ErRobNc	Res	lamp	$2.86	0.08	$72.26	$5.75	$0.00	$8.61	-							
		Measure	LED A-Lamp, Energy Star, low brightness (9 watts)	ErRobNc	Res	lamp	$28.29	0.08	$72.26	$5.75	$0.00	$34.05	$25.44							
		Baseline	Incandescent A-Lamp, EISA, 1,500 hours, medium brightness (60 watts)	ErRobNc	Res	lamp	$1.41	0.08	$72.26	$5.75	$0.00	$7.17	-							
		Measure	LED A-Lamp, Energy Star, medium brightness (12 watts)	ErRobNc	Res	lamp	$34.42	0.08	$72.26	$5.75	$0.00	$40.17	$33.01							
		Baseline	CFL Twister, 20,000 hours, medium brightness (15 watts)	ErRobNc	Res	lamp	$3.19	0.08	$72.26	$5.75	$0.00	$8.94	-							
		Measure	LED A-Lamp, Energy Star, medium brightness (12 watts)	ErRobNc	Res	lamp	$34.42	0.08	$72.26	$5.75	$0.00	$40.17	$31.23							
LED Reflector	Example Measures	Baseline	Incandescent Reflector, 2,000 hours, medium brightness (60 watts)	ErRobNc	Res	lamp	$6.16	0.06	$72.26	$4.48	$0.00	$10.64	-							
		Measure	LED Reflector, Energy Star, medium brightness (15 watts)	ErRobNc	Res	lamp	$48.10	0.06	$72.26	$4.48	$0.00	$52.58	$41.94							
		Baseline	CFL Reflector, medium brightness (15 watts)	ErRobNc	Res	lamp	$7.84	0.06	$72.26	$4.48	$0.00	$12.32	-							
		Measure	LED Reflector, Energy Star, medium brightness (15 watts)	ErRobNc	Res	lamp	$48.10	0.06	$72.26	$4.48	$0.00	$52.58	$40.27							
		Baseline	Incandescent Reflector, 2,000 hours, high brightness (90 watts)	ErRobNc	Res	lamp	$6.47	0.06	$72.26	$4.48	$0.00	$10.95	-							
		Measure	LED Reflector, Energy Star, high brightness (22 watts)	ErRobNc	Res	lamp	$57.94	0.06	$72.26	$4.48	$0.00	$62.42	$51.47							
		Baseline	CFL Reflector, high brightness (25 watts)	ErRobNc	Res	lamp	$9.31	0.06	$72.26	$4.48	$0.00	$13.79	-							
		Measure	LED Reflector, Energy Star, high brightness (22 watts)	ErRobNc	Res	lamp	$57.94	0.06	$72.26	$4.48	$0.00	$62.42	$48.63							
LED Globe	Example Measures	Baseline	Incandescent Globe, 2,000 hours, low brightness (40 watts)	ErRobNc	Res	lamp	$4.75	0.05	$72.26	$3.61	$0.00	$8.37	-							
		Measure	LED Globe, Energy Star, 30,000 hours, low brightness (8 watts)	ErRobNc	Res	lamp	$31.21	0.05	$72.26	$3.61	$0.00	$34.82	$26.45							
		Baseline	CFL Globe	ErRobNc	Res	lamp	$7.62	0.05	$72.26	$3.61	$0.00	$11.23	-							
		Measure	LED Globe, Energy Star, 30,000 hours, low brightness (8 watts)	ErRobNc	Res	lamp	$31.21	0.05	$72.26	$3.61	$0.00	$34.82	$23.59							
LED Torpedo	Example Measures	Baseline	Incandscent Torpedo, 2,000 hours	ErRobNc	Res	lamp	$2.05	0.08	$72.26	$5.75	$0.00	$7.81	-							
		Measure	LED Torpedo, low brightness (4 watts)	ErRobNc	Res	lamp	$16.07	0.08	$72.26	$5.75	$0.00	$21.83	$14.02							
		Baseline	CFL Torpedo, 10,000 hours, low brightness (11 watts)	ErRobNc	Res	lamp	$8.24	0.08	$72.26	$5.75	$0.00	$14.00	-							
		Measure	LED Torpedo, low brightness (4 watts)	ErRobNc	Res	lamp	$16.07	0.08	$72.26	$5.75	$0.00	$21.83	$7.83							

	Measure Information						Total Costs							Per Unit Costs						
Technology	READI Index ID	Match Pair	Description	Measure Type	Sector	Unit	Equipment Cost	Labor Hours	CA Average Labor Rate	Labor Cost	Misc. Costs	Full Installed Cost	Incremental Cost	Equipment Cost per unit	Labor Cost per Unit	Misc. Costs Per Unit	Misc. Fixed Costs per Project	Full Cost per Unit	Incremental Cost per Unit	Incremental Fixed Cost per Project
HID Lamps	2183	Baseline	HID lamp and ballast: 43 Watt Metal Halide lamp (1); Reactor Ballast (1), Total fixture Watts = 43 fixture watts out of sample	ErRul	Com	Fixture														
	2183	Measure	HID lamp and ballast: 43 Watt Metal Halide lamp (1); Reactor Ballast (1), Total fixture Watts = 43 fixture watts out of sample	ErRul	Com	Fixture														
	2184, 2185	Baseline	HID lamp and ballast: 208 Watt Pulse Start Metal Halide lamp (1); CWA Ballast (1), Total fixture Watts = 208 assumed 18 in fixture, 120 lm/watt, 3500k, 90 CRI measure same as standard	ErRul	Com	Fixture	$251.76	1.58	$72.01	$113.71	$35.18	$400.65	-							
	2184	Measure	HID lamp and ballast: 208 Watt Pulse Start Metal Halide lamp (1); CWA Ballast (1), Total fixture Watts = 208 assumed 18 in fixture, 120 lm/watt, 3500k, 90 CRI	ErRul	Com	Fixture	$251.76	1.58	$72.01	$113.71	$35.18	$400.65	$0.00							
	2185	Measure	HID lamp and ballast: 208 Watt Pulse Start Metal Halide lamp (1); CWA Ballast (1), Total fixture Watts = 208 assumed 18 in fixture, 120 lm/watt, 3500k, 90 CRI	ErRul	Com	Fixture	$251.76	1.58	$72.01	$113.71	$35.18	$400.65	$0.00							
	2186, 2187	Baseline	HID lamp and ballast: 288 Watt Pulse Start Metal Halide lamp (1); CWA Ballast (1), Total fixture Watts = 288 assumed 18 in fixture, 120 lm/watt, 3500k, 90 CRI, measure same as standard	ErRul	Com	Fixture	$258.07	1.58	$72.01	$113.71	$35.18	$406.96	-							
	2186	Measure	HID lamp and ballast: 288 Watt Pulse Start Metal Halide lamp (1); CWA Ballast (1), Total fixture Watts = 288 assumed 18 in fixture, 120 lm/watt, 3500k, 90 CRI	ErRul	Com	Fixture	$258.07	1.58	$72.01	$113.71	$35.18	$406.96	$0.00							
	2187	Measure	HID lamp and ballast: 288 Watt Pulse Start Metal Halide lamp (1); CWA Ballast (1), Total fixture Watts = 288 assumed 18 in fixture, 120 lm/watt, 3500k, 90 CRI	ErRul	Com	Fixture	$258.07	1.58	$72.01	$113.71	$35.18	$406.96	$0.00							
	2188, 2189	Baseline	HID lamp and ballast: 400 Watt Pulse Start Metal Halide lamp (1); CWA Ballast (1), Total fixture Watts = 400 assumed 18 in fixture, 120 lm/watt, 3500k, 90 CRI, measure same as standard	ErRul	Com	Fixture	$266.91	1.58	$72.01	$113.71	$35.18	$415.80	-							
	2188	Measure	HID lamp and ballast: 400 Watt Pulse Start Metal Halide lamp (1); CWA Ballast (1), Total fixture Watts = 400 assumed 18 in fixture, 120 lm/watt, 3500k, 90 CRI	ErRul	Com	Fixture	$266.91	1.58	$72.01	$113.71	$35.18	$415.80	$0.00							
	2189	Measure	HID lamp and ballast: 400 Watt Pulse Start Metal Halide lamp (1); CWA Ballast (1), Total fixture Watts = 400 assumed 18 in fixture, 120 lm/watt, 3500k, 90 CRI	ErRul	Com	Fixture	$266.91	1.58	$72.01	$113.71	$35.18	$415.80	$0.00							
Lighting - Linear Fluorescents																				
LF Ballasts + Lamps	2003	Baseline	LF lamp and ballast: LF lamp: T5, 46inch, 28W, 2895 lm, CRI=85, rated hours = 25000 (1); LF Ballast: Electronic, Programmed Start, High LO (1); Total Fixture Watts = 33 assumed cee/nema certified, 0.98 BF	ErRul	Com	lamp + ballast	$54.74	2.39	$72.55	$173.10	$0.00	$227.83	-							
	2003	Measure	LF lamp and ballast: LF lamp: T5, 46inch, 28W, 2895 lm, CRI=85, rated hours = 25000 (1); LF Ballast: Electronic, Programmed Start, High LO (1); Total Fixture Watts = 33 assumed cee/nema certified, 0.98 BF - same as baseline	ErRul	Com	lamp + ballast	$54.74	2.39	$72.55	$173.10	$0.00	$227.83	$0.00							
	2004	Baseline	LF lamp and ballast: LF lamp: T5, 46inch, 28W, 2895 lm, CRI=85, rated hours = 25000 (2); LF Ballast: Electronic, Programmed Start, High LO (1); Total Fixture Watts = 64 assumed cee/nema certified, 0.98 BF	ErRul	Com	lamp + ballast	$71.76	2.39	$72.55	$173.10	$0.00	$244.85	-							
	2004	Measure	LF lamp and ballast: LF lamp: T5, 46inch, 28W, 2895 lm, CRI=85, rated hours = 25000 (2); LF Ballast: Electronic, Programmed Start, High LO (1); Total Fixture Watts = 64 assumed cee/nema certified, 0.98 BF - same as baseline	ErRul	Com	lamp + ballast	$71.76	2.39	$72.55	$173.10	$0.00	$244.85	$0.00							
	2005	Baseline	LF lamp and ballast: LF lamp: T5, 46inch, 28W, 2895 lm, CRI=85, rated hours = 25000 (2); LF Ballast: Electronic, Programmed Start, High LO (1); Total Fixture Watts = 64 assumed cee/nema certified, 0.98 BF	ErRul	Com	lamp + ballast	$71.76	2.39	$72.55	$173.10	$0.00	$244.85	-							
	2005	Measure	LF lamp and ballast: LF lamp: T5, 46inch, 28W, 2895 lm, CRI=85, rated hours = 25000 (2); LF Ballast: Electronic, Programmed Start, High LO (1); Total Fixture Watts = 64 assumed cee/nema certified, 0.98 BF - same as baseline	ErRul	Com	lamp + ballast	$71.76	2.39	$72.55	$173.10	$0.00	$244.85	$0.00							
	2006	Baseline	LF lamp and ballast: LF lamp: T5, 46inch, 28W, 2895 lm, CRI=85, rated hours = 25000 (3); LF Ballast: Electronic, Programmed Start, High LO (2); Total Fixture Watts = 97 assumed cee/nema certified, 0.98 BF	ErRul	Com	lamp + ballast	$140.02	2.39	$72.55	$173.10	$0.00	$313.11	-							
	2006	Measure	LF lamp and ballast: LF lamp: T5, 46inch, 28W, 2895 lm, CRI=85, rated hours = 25000 (3); LF Ballast: Electronic, Programmed Start, High LO (2); Total Fixture Watts = 97 assumed cee/nema certified, 0.98 BF - same as baseline	ErRul	Com	lamp + ballast	$140.02	2.39	$72.55	$173.10	$0.00	$313.11	$0.00							
	2007	Baseline	LF lamp and ballast: LF lamp: T5, 46inch, 28W, 2895 lm, CRI=85, rated hours = 25000 (3); LF Ballast: Electronic, Programmed Start, High LO (2); Total Fixture Watts = 97 assumed cee/nema certified, 0.98 BF	ErRul	Com	lamp + ballast	$140.02	2.39	$72.55	$173.10	$0.00	$313.11	-							
	2007	Measure	LF lamp and ballast: LF lamp: T5, 46inch, 28W, 2895 lm, CRI=85, rated hours = 25000 (3); LF Ballast: Electronic, Programmed Start, High LO (2); Total Fixture Watts = 97 assumed cee/nema certified, 0.98 BF - same as baseline	ErRul	Com	lamp + ballast	$140.02	2.39	$72.55	$173.10	$0.00	$313.11	$0.00							
	2008, 2009	Baseline	LF lamp and ballast: LF lamp: T5, 46inch, 54W, 5000 lm, CRI=85, rated hours = 25000 (1); LF Ballast: Electronic, Programmed Start, High LO (0.5); Total Fixture Watts = 59 assumed cee/nema certified, 0.98 BF	ErRul	Com	lamp + ballast	$58.51	2.39	$72.55	$173.10	$0.00	$231.60	-							
	2008	Measure	LF lamp and ballast: LF lamp: T5, 46inch, 54W, 5000 lm, CRI=85, rated hours = 25000 (1); LF Ballast: Electronic, Programmed Start, High LO (0.5); Total Fixture Watts = 59 assumed cee/nema certified, 0.98 BF - same as baseline	ErRul	Com	lamp + ballast	$58.51	2.39	$72.55	$173.10	$0.00	$231.60	$0.00							

	Measure Information						Total Costs							Per Unit Costs						
Technology	READI Index ID	Match Pair	Description	Measure Type	Sector	Unit	Equipment Cost	Labor Hours	CA Average Labor Rate	Labor Cost	Misc. Costs	Full Installed Cost	Incremental Cost	Equipment Cost per unit	Labor Cost per Unit	Misc. Costs Per Unit	Misc. Fixed Costs per Project	Full Cost per Unit	Incremental Cost per Unit	Incremental Fixed Cost per Project
LF Ballasts + Lamps	2009	Baseline	LF lamp and ballast: LF lamp: T5, 46inch, 54W, 5000 lm, CRI=85, rated hours = 25000 (1); LF Ballast: Electronic, Programmed Start, High LO (1); Total Fixture Watts = 62 assumed cee/nema certified, 0.98 BF	ErRul	Com	lamp + ballast	$58.51	2.39	$72.55	$173.10	$0.00	$231.60	-							
	2009	Measure	LF lamp and ballast: LF lamp: T5, 46inch, 54W, 5000 lm, CRI=85, rated hours = 25000 (1); LF Ballast: Electronic, Programmed Start, High LO (1); Total Fixture Watts = 62 assumed cee/nema certified, 0.98 BF - same as baseline	ErRul	Com	lamp + ballast	$58.51	2.39	$72.55	$173.10	$0.00	$231.60	$0.00							
	2010	Baseline	LF lamp and ballast: LF lamp: T5, 46inch, 54W, 5000 lm, CRI=85, rated hours = 25000 (2); LF Ballast: Electronic, Programmed Start, High LO (1); Total Fixture Watts = 117 assumed cee/nema certified, 0.98 BF	ErRul	Com	lamp + ballast	$79.30	2.39	$72.55	$173.10	$0.00	$252.39	-							
	2010	Measure	LF lamp and ballast: LF lamp: T5, 46inch, 54W, 5000 lm, CRI=85, rated hours = 25000 (2); LF Ballast: Electronic, Programmed Start, High LO (1); Total Fixture Watts = 117 assumed cee/nema certified, 0.98 BF - same as baseline	ErRul	Com	lamp + ballast	$79.30	2.39	$72.55	$173.10	$0.00	$252.39	$0.00							
	2011	Baseline	HID lamp and ballast: 365 Watt Pulse Start Metal Halide lamp (1); CWA Ballast (1), Total fixture Watts = 365 assume 65 lm/W, 3650 color temp, 76.5 CRI assume high bay	RobNc	Com	lamp + ballast	$242.91	2.13	$67.26	$143.44	$43.71	$430.05	-							
	2011	Measure	LF lamp and ballast: LF lamp: T5, 46inch, 54W, 5000 lm, CRI=85, rated hours = 25000 (4); LF Ballast: Electronic, Programmed Start, High LO (1); Total Fixture Watts = 234 assumed cee/nema certified, 0.98 BF assume high bay	RobNc	Com	lamp + ballast	$120.88	2.13	$67.26	$143.44	$43.71	$308.02	-$122.03							
	2012	Baseline	HID lamp and ballast: 456 Watt Pulse Start Metal Halide lamp (1); CWA Ballast (1), Total fixture Watts = 456 assume 65 lm/W, 3650 color temp, 76.5 CRI assume high bay	RobNc	Com	lamp + ballast	$244.63	2.13	$67.26	$143.44	$43.71	$431.77	-							
	2012	Measure	LF lamp and ballast: LF lamp: T5, 46inch, 54W, 5000 lm, CRI=85, rated hours = 25000 (6); LF Ballast: Electronic, Programmed Start, High LO (2); Total Fixture Watts = 351 assumed cee/nema certified, 0.98 BF assume high bay	RobNc	Com	lamp + ballast	$252.35	2.13	$67.26	$143.44	$43.71	$439.49	$7.72							
	2013	Baseline	LF lamp and ballast: LF lamp: T5, 46inch, 54W, 5000 lm, CRI=85, rated hours = 25000 (6); LF Ballast: Electronic, Programmed Start, High LO (2); Total Fixture Watts = 351 assumed cee/nema certified, 0.98 BF	ErRul	Com	lamp + ballast	$252.35	3.31	$72.55	$239.98	$0.00	$492.33	-							
	2013	Measure	LF lamp and ballast: LF lamp: T5, 46inch, 54W, 5000 lm, CRI=85, rated hours = 25000 (6); LF Ballast: Electronic, Programmed Start, High LO (2); Total Fixture Watts = 351 assumed cee/nema certified, 0.98 BF - same as baseline	ErRul	Com	lamp + ballast	$252.35	2.39	$72.55	$173.10	$0.00	$425.44	-$66.89							
	2014	Baseline	LF lamp and ballast: LF lamp: T5, 46inch, 54W, 5000 lm, CRI=85, rated hours = 25000 (4); LF Ballast: Electronic, Programmed Start, High LO (1); Total Fixture Watts = 234 assumed cee/nema certified, 0.98 BF	ErRul	Com	lamp + ballast	$120.88	2.39	$72.55	$173.10	$0.00	$293.98	-							
	2014	Measure	LF lamp and ballast: LF lamp: T5, 46inch, 54W, 5000 lm, CRI=85, rated hours = 25000 (4); LF Ballast: Electronic, Programmed Start, High LO (1); Total Fixture Watts = 234 assumed cee/nema certified, 0.98 BF - same as baseline	ErRul	Com	lamp + ballast	$120.88	2.39	$72.55	$173.10	$0.00	$293.98	$0.00							
	2015	Baseline	HID lamp and ballast: 365 Watt Pulse Start Metal Halide lamp (1); CWA Ballast (1), Total fixture Watts = 365 assume 65 lm/W, 3650 color temp, 76.5 CRI assume high bay	ErRobNc	Com	lamp + ballast	$242.91	2.13	$67.26	$143.44	$43.71	$430.05	-							
	2015	Measure	LF lamp and ballast: LF lamp: T5, 46inch, 54W, 5000 lm, CRI=85, rated hours = 25000 (4); LF Ballast: Electronic, Programmed Start, High LO (1); Total Fixture Watts = 234 assumed cee/nema certified, 0.98 BF assume high bay	ErRobNc	Com	lamp + ballast	$120.88	2.13	$67.26	$143.44	$43.71	$308.02	-$122.03							
	2016	Baseline	LF lamp and ballast: LF lamp: T5, 46inch, 54W, 5000 lm, CRI=85, rated hours = 25000 (6); LF Ballast: Electronic, Programmed Start, High LO (2); Total Fixture Watts = 351 assumed cee/nema certified, 0.98 BF	ErRul	Com	lamp + ballast	$252.35	2.39	$72.55	$173.10	$0.00	$425.44	-							
	2016	Measure	LF lamp and ballast: LF lamp: T5, 46inch, 54W, 5000 lm, CRI=85, rated hours = 25000 (6); LF Ballast: Electronic, Programmed Start, High LO (2); Total Fixture Watts = 351 assumed cee/nema certified, 0.98 BF - same as baseline	ErRul	Com	lamp + ballast	$252.35	2.39	$72.55	$173.10	$0.00	$425.44	$0.00							
	2017	Baseline	HID lamp and ballast: 456 Watt Pulse Start Metal Halide lamp (1); CWA Ballast (1), Total fixture Watts = 456 assume 65 lm/W, 3650 color temp, 76.5 CRI assume high bay	ErRobNc	Com	lamp + ballast	$244.63	2.13	$67.26	$143.44	$43.71	$431.77	-							
	2017	Measure	LF lamp and ballast: LF lamp: T5, 46inch, 54W, 5000 lm, CRI=85, rated hours = 25000 (6); LF Ballast: Electronic, Programmed Start, High LO (2); Total Fixture Watts = 351 assumed cee/nema certified, 0.98 BF assume high bay	ErRobNc	Com	lamp + ballast	$252.35	2.13	$67.26	$143.44	$43.71	$439.49	$7.72							

	Measure Information						Total Costs							Per Unit Costs						
Technology	READI Index ID	Match Pair	Description	Measure Type	Sector	Unit	Equipment Cost	Labor Hours	CA Average Labor Rate	Labor Cost	Misc. Costs	Full Installed Cost	Incremental Cost	Equipment Cost per unit	Labor Cost per Unit	Misc. Costs Per Unit	Misc. Fixed Costs per Project	Full Cost per Unit	Incremental Cost per Unit	Incremental Fixed Cost per Project
LF Fixtures + Lamps	2024, 2026, 2028, 2030, 2032	Baseline	LF fixture: T8, 48inch, 32W lamp (1), Total fixture Watts = 32; Ballast specs: Rapid Start, Electronic, NLO, 1 per lamp; Lamp specs: 2900 lumens, CRI=75, rated hours = 15000 assume surface mounted	ErRobNc	Com	fixture	$146.48	1.84	$74.91	$137.80	$24.30	$308.58	-							
	2024	Measure	LF fixture: T8, 48inch, 32W lamp (1), Total fixture Watts = 31; Ballast specs: Instant Start, Electronic, NLO, 1 per lamp; Lamp specs: 3175 lumens, CRI=82, rated hours = 20000 assume surface mounted	ErRobNc	Com	fixture	$79.43	1.84	$74.91	$137.80	$24.30	$241.53	-$67.05							
	2026	Measure	LF fixture: T8, 48inch, 32W lamp (1), Total fixture Watts = 31; Ballast specs: Instant Start, Electronic, NLO, 1 per lamp; Lamp specs: 3175 lumens, CRI=82, rated hours = 20000 assume surface mounted	ErRobNc	Com	fixture	$79.43	1.84	$74.91	$137.80	$24.30	$241.53	-$67.05							
	2028	Measure	LF fixture: T8, 48inch, 32W lamp (1), Total fixture Watts = 31; Ballast specs: Instant Start, Electronic, NLO, 1 per lamp; Lamp specs: 3175 lumens, CRI=82, rated hours = 20000 assume surface mounted	ErRobNc	Com	fixture	$79.43	1.84	$74.91	$137.80	$24.30	$241.53	-$67.05							
	2030	Measure	LF fixture: T8, 48inch, 32W lamp (1), Total fixture Watts = 31; Ballast specs: Instant Start, Electronic, NLO, 1 per lamp; Lamp specs: 3175 lumens, CRI=82, rated hours = 20000 assume surface mounted	ErRobNc	Com	fixture	$79.43	1.84	$74.91	$137.80	$24.30	$241.53	-$67.05							
	2032	Measure	LF fixture: T8, 48inch, 32W lamp (1), Total fixture Watts = 31; Ballast specs: Instant Start, Electronic, NLO, 1 per lamp; Lamp specs: 3175 lumens, CRI=82, rated hours = 20000 assume surface mounted	ErRobNc	Com	fixture	$79.43	1.84	$74.91	$137.80	$24.30	$241.53	-$67.05							
	2034, 2036, 2037, 204	Baseline	LF fixture: T8, 48inch, 32W lamp (2), Total fixture Watts = 60; Ballast specs: Rapid Start, Electronic, NLO, 2 per lamp; Lamp specs: 2900 lumens, CRI=75, rated hours = 15000 assume surface mounted	ErRobNc	Com	fixture	$156.61	1.84	$74.91	$137.80	$24.30	$318.71	-							
	2034	Measure	LF fixture: T8, 48inch, 32W lamp (2), Total fixture Watts = 54; Ballast specs: Rapid Start, Electronic, RLO, 2 per lamp; Lamp specs: 3175 lumens, CRI=70, rated hours = 20000 assume surface mounted	ErRobNc	Com	fixture	$154.23	1.84	$74.91	$137.80	$24.30	$316.34	-$2.38							
	2036	Measure	LF fixture: T8, 48inch, 32W lamp (1), Total fixture Watts = 41; Ballast specs: Instant Start, Electronic, VHLO, 1 per lamp; Lamp specs: 3175 lumens, CRI=70, rated hours = 20000 assume surface mounted	ErRobNc	Com	fixture	$77.18	1.84	$74.91	$137.80	$24.30	$239.28	-$79.43							
	2037	Measure	LF fixture: T8, 48inch, 32W lamp (2), Total fixture Watts = 54; Ballast specs: Rapid Start, Electronic, RLO, 2 per lamp; Lamp specs: 3175 lumens, CRI=70, rated hours = 20000 assume surface mounted	ErRobNc	Com	fixture	$154.23	1.84	$74.91	$137.80	$24.30	$316.34	-$2.38							
	2040	Measure	LF fixture: T8, 48inch, 32W lamp (2), Total fixture Watts = 54; Ballast specs: Rapid Start, Electronic, RLO, 2 per lamp; Lamp specs: 3175 lumens, CRI=70, rated hours = 20000 assume surface mounted	ErRobNc	Com	fixture	$154.23	1.84	$74.91	$137.80	$24.30	$316.34	-$2.38							
	Example Measures	Baseline	T8, 36 inch, 2-lamp, 25 watt, instant start ballast, recessed troffer w/cover 25 watt, 2175 lumens, 87 lumens per watt, CRI 85 ladder accessible	ErRobNc	Com	fixture	$294.38	1.95	$74.91	$145.80	$16.02	$456.19	-							
		Measure	T8, 36 inch, 2-lamp, 21 watt, instant start ballast, recessed troffer w/cover 2100 lumens, 100 lumens per watt, CRI 85 ladder accessible	ErRobNc	Com	fixture	$301.53	1.95	$74.91	$145.80	$16.02	$463.35	$7.15							
		Baseline	T8, 96 inch, 2-lamp, 59 watt, instant start ballast, recessed troffer no cover (lamps not included) 57000 lumens, 36000 hr rated life, 95 lumens per watt, CRI 85 ladder accessible	ErRobNc	Com	fixture	$443.41	1.95	$74.91	$145.80	$16.02	$605.22	-							
		Measure	T8, 96 inch, 2-lamp, 55 watt, program start ballast, recessed troffer no cover 57000 lumens, 36000 hr rated life, 103 lumens per watt, CRI 85 ladder accessible	ErRobNc	Com	fixture	$480.97	1.95	$74.91	$145.80	$16.02	$642.78	$37.56							
		Baseline	T8, 48 inch, 2-lamp, 32 watt, instant start ballast, suspended low bay 2850 lumens, 24000 hr rated life, 89 lumens per watt, CRI 85 ladder accessible	ErRobNc	Com	fixture	$354.02	1.84	$74.91	$137.80	$24.30	$516.12	-							
		Measure	T5, 48 inch, 2-lamp, 28 watt, program start ballast, suspended low bay (lamps not included) 2895 lumens, 24000 hr rated life, 103 lumens per watt, CRI 85 ladder accessible	ErRobNc	Com	fixture	$361.59	1.84	$74.91	$137.80	$24.30	$523.70	$7.57							
High Bay Linear Fluorescent Fixtures	Example Measures	Base	HID lamp and ballast: 400 Watt Pulse Start Metal Halide lamp (1); CWA Ballast (1), Total fixture Watts = 400 assumed 18 in fixture, 120 lm/watt, 3500k, 90 CRI	ErRul	Com	Fixture	$266.91	2.13	$67.26	$143.44	$43.71	$454.05	-							
		Measure	T5, 48 inch, 6-lamp, 54 watt, program start ballast assumed 93 lm/w cri 85	ErRul	Com	Fixture	$323.93	2.13	$67.26	$143.44	$43.71	$511.07	$57.02							
		Base	T8, 96 inch, 4-lamp, 59 watt, instant start ballast assumed 97 lm/w cri 85, 36,000 hr	ErRul	Com	Fixture	$469.52	2.13	$67.26	$143.44	$43.71	$656.66	-							
		Measure	T5, 48 inch, 6-lamp, 54 watt, program start ballast assumed 95 lm/w cri 85	ErRul	Com	Fixture	$323.93	2.13	$67.26	$143.44	$43.71	$511.07	-$145.59							
Bi-Level Linear Fluorescent Fixtures (garage/stairwell lighting)	Workpaper measure	Baseline	T8, 48 inch, 2-lamp, 32 watt, instant start ballast, surface mounted wrap (lamps not included)	ErRobNC	Com	Fixture	$56.87	1.26	$75.45	$95.28	$24.30	$176.46	-							
		Measure	Two lamp 4 foot 64 watt linear fluorescent fixture with integrated occupancy sensor - no dimming or emergency ballast	ErRobNC	Com	Fixture	$273.64	1.32	$75.46	$99.52	$28.19	$401.35	$224.89							
	Example Measure	Measure	Two lamp 4 foot 64 watt linear fluorescent fixture with integrated occupancy sensor - no dimming w/ emergency ballast	ErRobNC	Com	Fixture	$414.17	1.32	$75.46	$99.52	$28.19	$541.88	$365.42							
		Measure	Two lamp 4 foot 64 watt linear fluorescent fixture with integrated occupancy sensor - w/ dimming w/ emergency ballast	ErRobNC	Com	Fixture	$468.97	1.32	$75.46	$99.52	$28.19	$596.68	$420.22							
Lighting - Controls																				
Photocells (sensor only)	9003 - 9007	Baseline	No Controls (T24 glazing performance matches prototype level, no controls installed)	RobNc	Com	Sensor	$0.00	0.00	$0.00	$0.00	$0.00	$0.00	-							
	9003	Measure	DayLtg Controls, Side Ltg, Cont. Ctrl	RobNc	Com	Sensor	$115.39	3.16	$87.05	$275.00	$15.86	$406.25	$406.25							
	9004	Measure	DayLtg Controls, Side Ltg, 2-step Ctrl	RobNc	Com	Sensor	$115.39	3.16	$87.05	$275.00	$15.86	$406.25	$406.25							
	9005	Measure	DayLtg Controls, Top Ltg, Cont. Ctrl	RobNc	Com	Sensor	$104.70	3.16	$87.05	$275.00	$15.86	$395.57	$395.57							
	9006	Measure	DayLtg Controls, Top Ltg, 1-step Ctrl	RobNc	Com	Sensor	$104.70	3.16	$87.05	$275.00	$15.86	$395.57	$395.57							
	9007	Measure	DayLtg Controls, Top Ltg, 2-step Ctrl	RobNc	Com	Sensor	$104.70	3.16	$87.05	$275.00	$15.86	$395.57	$395.57							

	Measure Information						Total Costs							Per Unit Costs						
Technology	**READI Index ID**	**Match Pair**	**Description**	**Measure Type**	**Sector**	**Unit**	**Equipment Cost**	**Labor Hours**	**CA Average Labor Rate**	**Labor Cost**	**Misc. Costs**	**Full Installed Cost**	**Incremental Cost**	**Equipment Cost per unit**	**Labor Cost per Unit**	**Misc. Costs Per Unit**	**Misc. Fixed Costs per Project**	**Full Cost per Unit**	**Incremental Cost per Unit**	**Incremental Fixed Cost per Project**
Occupancy Sensors	9001, 9002	Baseline	No Controls (T24 code baseline matches prototype)	RobNc	Com	Sensor	$0.00	0.00	$71.25	$0.00	$0.00	$0.00	-							
	9001	Measure	Occupancy Sensor Pack-200 SF assume wall mounted	ROB	Com	Sensor	$138.20	1.19	$71.25	$85.12	$6.73	$230.05	$230.05							
	9002	Measure	Occupancy Sensor Pack-1000 SF assume ceiling mounted	RobNc	Com	Sensor	$144.20	1.51	$71.25	$107.58	$16.53	$268.31	$268.31							
Residential Building Shell																				
Batt Insulation	23 - 27, 9009, 9105 - 9113	Baseline	No insulation or vintage-specific existing	ROB	Res	sqft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0.00	$0.00	$0.00	$0.00	0		-
	23	Measure	Ceiling R-0 to R-30 Insulation-Batts assume 16" wide and 43 sqft per package	ROB	Res	sqft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0.59	$0.81	$0.00	$0.00	$1.40	$1.40	$0.00
	24	Measure	Ceiling R-0 to R-38 Insulation-Batts assume 16" wide and 43 sqft per package	ROB	Res	sqft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0.72	$0.81	$0.00	$0.00	$1.53	$1.53	$0.00
	25	Measure	Ceiling - Add R-11 batts on top of vintage-specific existing insulation assume 16" wide and 43 sqft per package	ROB	Res	sqft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0.28	$0.81	$0.00	$0.00	$1.09	$1.09	$0.00
	26	Measure	Ceiling - Add R-19 batts on top of vintage-specific existing insulation assume 16" wide and 43 sqft per package	ROB	Res	sqft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0.41	$0.81	$0.00	$0.00	$1.22	$1.22	$0.00
	27	Measure	Ceiling - Add R-30 batts on top of vintage-specific existing insulation assume 16" wide and 43 sqft per package	ROB	Res	sqft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0.59	$0.81	$0.00	$0.00	$1.40	$1.40	$0.00
	9009	Measure	Ceiling/Roof Insulation assume R-20 16" wide and 43 sqft per package	ErRul	Com	sqft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0.42	$0.81	$0.00	$0.00	$1.24	$1.24	$0.00
	9105	Measure	Floor R-0 to R-19 Insulation Batts assume 16" wide and 43 sqft per package	ROB	Res	sqft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0.41	$0.81	$0.00	$0.00	$1.22	$1.22	$0.00
	9106	Measure	Floor R-0 to R-30 Insulation Batts assume 16" wide and 43 sqft per package	ROB	Res	sqft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0.59	$0.81	$0.00	$0.00	$1.40	$1.40	$0.00
	9107	Measure	Floor R-19 to R-30 Insulation-Batts assume 16" wide and 43 sqft per package	ROB	Res	sqft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0.28	$0.81	$0.00	$0.00	$1.09	$1.09	$0.00
	9108	Measure	Wall 2x4 R-15 Insulation-Batts assume 16" wide and 43 sqft per package	ROB	Res	sqft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0.34	$0.81	$0.00	$0.00	$1.15	$1.15	$0.00
	9109	Measure	Wall 2x6 R-19 Insulation-Batts assume 16" wide and 43 sqft per package	ROB	Res	sqft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0.41	$0.81	$0.00	$0.00	$1.22	$1.22	$0.00
	9110	Measure	Wall 2x6 R-21 Insulation-Batts assume 16" wide and 43 sqft per package	ROB	Res	sqft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0.44	$0.81	$0.00	$0.00	$1.25	$1.25	$0.00
	9111	Measure	Wall 2x4 R-13 Batts + R-5 Rigid assume 16" wide and 43 sqft per package COST DOES NOT INCLUDE R-5 RIGID	ROB	Res	sqft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0.31	$0.81	$0.00	$0.00	$1.12	$1.12	$0.00
	9112	Measure	Wall 2x6 R-19 Batts + R-5 Rigid assume 16" wide and 43 sqft per package COST DOES NOT INCLUDE R-5 RIGID	ROB	Res	sqft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0.41	$0.81	$0.00	$0.00	$1.22	$1.22	$0.00
	9113	Measure	Wall 2x6 R-21 Batts + R-5 Rigid assume 16" wide and 43 sqft per package COST DOES NOT INCLUDE R-5 RIGID	ROB	Res	sqft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0.44	$0.81	$0.00	$0.00	$1.25	$1.25	$0.00
Non-Residential Building Shell																				
Thermal Curtain	17, 18, 100178	Baseline	Absense of heat curtains	RobNc	Ag	sqft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0.00	$0.00	$0.00	$0.00	0	-	-
	17, , 100178	Measure	Heat curtain installed in greenhouse that has roofs with IR film and bare walls	RobNc	Ag	sqft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0.46	$0.17	$0.03	N/A	$0.66	$0.66	N/A
	18	Measure	Heat curtain installed in greenhouse with bare walls and bare double-poly roofs	RobNc	Ag	sqft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0.46	$0.17	$0.03	N/A	$0.66	$0.66	N/A
Reflective Film	100099, 100100	Baseline	Single pane clear glass windows SHGC 0.82	RobNc	Com/Res	sqft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$0.00	$0.00	$0.00	$0.00	0	-	-
	100099	Measure	Window Film added to existing windows SHGC 0.39 assumed 0.81 emmisivity, 0.63 glare reduction, 1.03 winter U-value, 26 reflected interior, 32 reflected exterior	RobNc	Com	sqft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$1.16	$3.33	$0.00	$0.00	$4.49	$4.49	N/A
	100100	Measure	Window Film added to existing windows SHGC 0.39 assumed 0.81 emmisivity, 0.63 glare reduction, 1.03 winter U-value, 26 reflected interior, 32 reflected exterior	RobNc	Res	sqft	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$1.16	$3.33	$0.00	$0.00	$4.49	$4.49	N/A

F.2 Simple Average and Built-Up Estimates

Measure	READI Index ID	Cost Unit	Cost Type	Sample Data				Analysis		Results Benchmarks			
				Source	N	Min Price	Max Price	Type	Result	DEER08	DEER05	DEER01	Other
Commercial Refrigeration (Supermarkets)													
ECM fan motors for walk-in coolers	100103-100108	Per motor	Materials	Distributors	4	$188.09	$227.21	Sample average	$226.20	$230.94	$167.43	N/A	N/A
			Labor	Estimate	N/A	$42.81		Estimate	$42.81	$73.65	$41.89	N/A	N/A
			Total	Built-up estimate	N/A	$230.90	$270.02	Built-up estimate	$269.01	$304.58	$209.32	N/A	see notes
ECM fan motors for doored display case		Per motor	Materials	Distributors	6	$105.34	$132.32	Sample average	$122.41	$230.94	$13.58	N/A	N/A
			Labor	Estimate	N/A	$18.30		Estimate	$18.30	$73.65	$13.67	N/A	N/A
			Total	Built-up estimate	N/A	$123.64	$150.62	Built-up estimate	$140.71	$304.58	$27.25	$161.00	see notes
ECM fan motors for open display case		Per motor	Materials	Distributors	6	$105.34	$132.32	Sample average	$122.41	$230.94	$13.58	N/A	N/A
			Labor	Estimate	N/A	$19.29		Estimate	$19.29	$73.65	$13.67	N/A	N/A
			Total	Built-up estimate	N/A	$124.62	$151.60	Built-up estimate	$141.70	$304.58	$27.25	$161.00	see notes
Medium temp glass doors (retrofit)	9086	Per linear ft upright display case	Materials	Distributors	3	$284.68	$385.00	Sample average	$320.84	N/A	$514.13	$105.00	N/A
			Labor	Estimate	N/A	$176.98		Estimate	$176.98	N/A	$99.81	N/A	N/A
			Total	Built-up estimate	N/A	$461.66	$561.98	Built-up estimate	$497.82	N/A	$613.95	N/A	see notes
Medium temp glass doors (new)	9087	Per linear ft upright display case	Materials	Distributors	2	$550.00	$774.19	Sample average	$686.29	$574.87	$515.58	N/A	N/A
			Labor	Estimate	N/A	$324.48		Estimate	$324.48	$331.41	$329.66	N/A	N/A
			Total	Built-up estimate	N/A	$874.48	$1,098.67	Built-up estimate	$1,010.77	$906.27	$845.24	N/A	see notes
Auto-closers on main cooler/freezer doors, <42" wide	100188, 100189	Per cooler door	Materials	Distributors	1	$155.67	$155.67	Sample average	$155.67	$120.00	$322.59	N/A	N/A
			Labor	Estimate	N/A	$70.78		Estimate	$70.78	$36.82	$110.63	N/A	N/A
			Total	Built-up estimate	N/A	$226.45	$226.45	Built-up estimate	$226.45	$156.82	$433.22	N/A	see notes
Auto-closers on main cooler/freezer doors, >42" wide	100188, 100189	Per cooler door	Materials	Distributors	1	$917.19	$917.19	Sample average	$917.19	$120.00	$322.59	N/A	N/A
			Labor	Estimate	N/A	$140.36		Estimate	$140.36	$36.82	$110.63	N/A	N/A
			Total	Built-up estimate	N/A	$1,057.55	$1,057.55	Built-up estimate	$1,057.55	$156.82	$433.22	N/A	see notes
Evaporator fan control on walk-in coolers/freezers (<1 hp)	100103-100108	Per motor	Materials	Distributors	4	$589.38	$675.30	Sample average	$420.95	$69.69	$62.50	N/A	N/A
			Labor	Estimate	N/A	$199.55		Estimate	$199.55	$92.06	$83.25	N/A	N/A
			Total	Built-up estimate	N/A	$788.92	$874.85	Built-up estimate	$620.50	$161.74	$145.75	$265.00	see notes
Evaporator fan control on walk-in coolers/freezers (>1 hp)		Per motor	Materials	Distributors	6	$1,212	$1,212	Sample average	$1,212	$69.69	$62.50	N/A	N/A
			Labor	Estimate	N/A	$762		Estimate	$762.14	$92.06	$83.25	N/A	N/A
			Total	Built-up estimate	N/A	$1,974.26	$1,974.26	Built-up estimate	$1,974.26	$161.74	$145.75	$265.00	see notes
Floating suction pressure (retrofit)	9090	Per suction group	Materials	Distributors	N/A	$0.00	$0.00	Sample average	$0.00	N/A	$13.18	N/A	N/A
			Labor	Estimate	N/A	$5,460.00		Estimate	$5,460.00	N/A	$26.78	N/A	N/A
			Total	Built-up estimate	N/A	$5,460.00	$5,460.00	Built-up estimate	$5,460.00	N/A	$39.96	N/A	see notes
Floating head pressure (FHP), fixed setpoint (FSP) (air-cooled, retrofit)	9091	Per discharge group	Materials	Distributors	1	$4,008.68	$4,008.68	Sample average	$4,008.68	N/A	$0.00	N/A	N/A
			Labor	Estimate	N/A	$4,673.43		Estimate	$4,673.43	N/A	$27.90	N/A	N/A
			Total	Built-up estimate	N/A	$8,682.11	$8,682.11	Built-up estimate	$8,682.11	N/A	$27.90	N/A	see notes
FHP, FSP (evap-cooled, retrofit)	9092	Per discharge group	Materials	Distributors	1	$4,008.68	$4,008.68	Sample average	$4,008.68	N/A	$0.00	N/A	N/A
			Labor	Estimate	N/A	$4,673.43		Estimate	$4,673.43	N/A	$27.90	N/A	N/A
			Total	Built-up estimate	N/A	$8,682.11	$8,682.11	Built-up estimate	$8,682.11	N/A	$27.90	N/A	see notes
FHP, variable setpoint (VSP) (air-cooled, retrofit)	9093	Per discharge group	Materials	Distributors	1	$4,406.24	$4,406.24	Sample average	$4,406.24	N/A	$10.04	N/A	N/A
			Labor	Estimate	N/A	$4,882.31		Estimate	$4,882.31	N/A	$40.92	N/A	N/A
			Total	Built-up estimate	N/A	$9,288.55	$9,288.55	Built-up estimate	$9,288.55	N/A	$50.95	N/A	see notes
FHP, VSP (evap-cooled, retrofit)	9094	Per discharge group	Materials	Distributors	1	$4,709.27	$4,709.27	Sample average	$4,709.27	N/A	$8.93	N/A	N/A
			Labor	Estimate	N/A	$4,897.46		Estimate	$4,897.46	N/A	$40.92	N/A	N/A
			Total	Built-up estimate	N/A	$9,606.73	$9,606.73	Built-up estimate	$9,606.73	N/A	$49.85	N/A	see notes
FHP, VSP & variable speed (VS) (air-cooled, retrofit)	9095	Per discharge group	Materials	Distributors	1	$6,241.47	$6,241.47	Sample average	$6,241.47	N/A	$294.33	N/A	N/A
			Labor	Estimate	N/A	$8,183.98		Estimate	$8,183.98	N/A	$91.66	N/A	N/A
			Total	Built-up estimate	N/A	$14,425.45	$14,425.45	Built-up estimate	$14,425.45	N/A	$385.99	N/A	see notes
FHP, VSP & VS (evap-cooled, retrofit)	9096	Per discharge group	Materials	Distributors	1	$7,390.00	$7,390.00	Sample average	$7,390.00	N/A	$151.97	N/A	N/A
			Labor	Estimate	N/A	$8,241.40		Estimate	$8,241.40	N/A	$68.92	N/A	N/A
			Total	Built-up estimate	N/A	$15,631.40	$15,631.40	Built-up estimate	$15,631.40	N/A	$220.89	N/A	see notes
Strip curtains on walk-Ins (doors <36" wide)	100094	Per square foot	Materials	Distributors	2	$5.06	$9.79	Sample average	$8.97	$7.50	N/A	N/A	N/A
			Labor	Estimate	N/A	$3.45		Estimate	$3.45	$2.72	N/A	N/A	N/A
			Total	Built-up estimate	N/A	$8.51	$13.24	Built-up estimate	$12.42	$10.22	N/A	N/A	see notes
Strip curtains on walk-Ins (doors >36" wide)	100094	Per square foot	Materials	Distributors	2	$5.06	$12.02	Sample average	$10.75	$7.50	N/A	N/A	N/A
			Labor	Estimate	N/A	$2.04		Estimate	$2.04	$2.72	N/A	N/A	N/A
			Total	Built-up estimate	N/A	$7.09	$14.06	Built-up estimate	$12.78	$10.22	N/A	N/A	see notes
LED lights in reach-in display cases		Per fixture	Materials	Distributors	1	$178.05	$178.05	Sample average	$178.05	N/A	N/A	N/A	N/A
			Labor	Estimate	N/A	$40.24		Estimate	$40.24	N/A	N/A	N/A	N/A
			Total	Built-up estimate	N/A	$218.29	$218.29	Built-up estimate	$218.29	N/A	N/A	N/A	see notes

Measure	READI Index ID	Cost Unit	Cost Type	Sample Data				Analysis		Results Benchmarks			
				Source	N	Min Price	Max Price	Type	Result	DEER08	DEER05	DEER01	Other
LED lights in open display cases		Per fixture	Materials	Distributors	1	$219.17	$219.17	Sample average	$219.17	N/A	N/A	N/A	N/A
			Labor	Estimate	N/A	$30.70		Estimate	$30.70	N/A	N/A	N/A	N/A
			Total	Built-up estimate	N/A	$249.87	$249.87	Built-up estimate	$249.87	N/A	N/A	N/A	see notes
Industrial Refrigeration (Refrigerated Warehouses)													
Floating suction pressure (retrofit)	9097	Per suction group	Materials	Distributors	1	$4,864.77	$4,864.77	Sample average	$4,864.77	N/A	$13.18	N/A	N/A
			Labor	Estimate	N/A	$7,876.74		Estimate	$7,876.74	N/A	$26.78	N/A	N/A
			Total	Built-up estimate	N/A	$12,741.51	$12,741.51	Built-up estimate	$12,741.51	N/A	$39.96	N/A	see notes
FHP, FSP (evap-cooled, retrofit)	9098	Per discharge group	Materials	Distributors	1	$2,012.18	$2,012.18	Sample average	$2,012.18	N/A	$0.00	N/A	N/A
			Labor	Estimate	N/A	$4,573.61		Estimate	$4,573.61	N/A	$27.90	N/A	N/A
			Total	Built-up estimate	N/A	$6,585.79	$6,585.79	Built-up estimate	$6,585.79	N/A	$27.90	N/A	see notes
FHP, VSP (evap-cooled, retrofit)	9099	Per discharge group	Materials	Distributors	1	$2,712.77	$2,712.77	Sample average	$2,712.77	N/A	$8.93	N/A	N/A
			Labor	Estimate	N/A	$4,797.64		Estimate	$4,797.64	N/A	$40.92	N/A	N/A
			Total	Built-up estimate	N/A	$7,510.41	$7,510.41	Built-up estimate	$7,510.41	N/A	$49.85	N/A	see notes
FHP, VSP & VS (evap-cooled, retrofit)	9100	Per discharge group	Materials	Distributors	1	$5,893.50	$5,893.50	Sample average	$5,893.50	N/A	$151.97	N/A	N/A
			Labor	Estimate	N/A	$8,241.16		Estimate	$8,241.16	N/A	$68.92	N/A	N/A
			Total	Built-up estimate	N/A	$14,134.66	$14,134.66	Built-up estimate	$14,134.66	N/A	$220.89	N/A	see notes
Food Service													
Electric fryer		Per unit production capacity (lbs/hr)	Materials	Distributors (4)	8	$ 53.85	$ 231.74	Baseline average	$ 105.76	N/A	$3,327	N/A	$4,108
			Materials		5	$ 30.48	$ 154.38	Measure average	$ 132.01	N/A	$12,089	N/A	$4,876
			Materials		13	N/A	N/A	Matched pair IMC	$ 27.25	N/A	-	N/A	-
			Materials*		13	N/A	N/A	Sample average IMC	$ 26.25	N/A	$8,762	N/A	$769
Gas fryer		Per unit production capacity (lbs/hr)	Materials	Distributors (2)	12	$ 24.73	$ 84.89	Baseline average	$ 32.90	N/A	$1,521	N/A	$3,367
			Materials		14	$ 11.43	$ 83.40	Measure average	$ 57.51	N/A	$4,103	N/A	$4,384
			Materials		28	N/A	N/A	Matched pair IMC	$ 30.28	N/A	-	N/A	-
			Materials*		28	N/A	N/A	Sample average IMC	$ 24.61	N/A	$2,583	N/A	$1,017
Electric convection oven (full size)		Per unit	Materials	Distributors (2)	5	$ 2,755	$ 6,763	Baseline average	$ 4,709	N/A	N/A	N/A	$4,108
			Materials		5	$ 2,850	$ 6,325	Measure average	$ 4,119	N/A	N/A	N/A	$5,115
			Materials		10	N/A	N/A	Matched pair IMC	$ (590)	N/A	N/A	N/A	-
			Materials*		10	N/A	N/A	Sample average IMC	$ (590)	N/A	N/A	N/A	$1,007
Gas convection oven (full size)		Per unit	Materials	Distributors (5)	2	$ 2,990	$ 3,112	Baseline average	$ 3,261	N/A	N/A	N/A	$4,349
			Materials		2	$ 3,243	$ 3,278	Measure average	$ 3,051	N/A	N/A	N/A	$5,526
			Materials		4	N/A	N/A	Matched pair IMC	$ (210)	N/A	N/A	N/A	-
			Materials*		4	N/A	N/A	Sample average IMC	$ (210)	N/A	N/A	N/A	$1,177
HVAC Maintenance													
Duct Testing and Sealing	169, 170-172, 10049, 10050, 10055, 10056, 10061, 10062, 100141, 100176	Per dwelling	Materials	DI contractors	2	$ 23.89	$ 119.00	Sample average	$ 71.45	$55.75	$16.67	N/A	N/A
			Labor		2	$ 171.00	$ 191.48	Sample average	$ 181.24	$441.87	$91.24	N/A	N/A
			Total		2	$ 194.89	$ 310.48	Sum of averages	$ 252.69	$497.62	$107.91	$614.00	N/A
			Total*		7	$ 113.00	$ 325.00	Sample average	$ 270.75	-	-	N/A	N/A
Refrigerant Charging and Adjustment	143, 144, 1179, 10045-10048, 10051-10054, 10057-10060, 10063-10070, 100134, 100135	Per ton cooling served	Materials	DI contractors	10	$ -	$ 28.00	Sample average	$ 9.92	$11.55	$14.11	N/A	N/A
			Labor		10	$ 9.00	$ 75.00	Sample average	$ 26.78	$36.82	$28.23	N/A	N/A
			Total		10	$ 9.00	$ 103.00	Sum of averages	$ 36.70	$48.37	$42.35	N/A	N/A
Evaporator Coil Cleaning (nonres)	100175	Per ton cooling served	Materials	DI contractors	5	$ -	$ 19.84	Sample average	$ 7.98	N/A	$0.00	N/A	N/A
			Labor		5	$ 15.87	$ 65.00	Sample average	$ 33.69	N/A	$35.11	N/A	N/A
			Total		5	$ 15.87	$ 84.84	Sum of averages	$ 41.67	N/A	$35.11	N/A	N/A
Condenser Coil Cleaning (nonres)	100119, 100120	Per ton cooling served	Materials	DI contractors	6	$ -	$ 17.54	Sample average	$ 6.73	N/A	N/A	N/A	N/A
			Labor		6	$ 14.03	$ 39.59	Sample average	$ 25.65	N/A	N/A	N/A	N/A
			Total		6	$ 14.03	$ 57.13	Sum of averages	$ 32.38	N/A	N/A	N/A	N/A
Economizer repair	9049, 100056, 100152, 100153	Per ton cooling served	Materials	DI contractors	11	$ 10.00	$ 43.73	Sample average	$ 19.64	$0.00	$0.00	N/A	N/A
			Labor		11	$ 6.38	$ 65.00	Sample average	$ 19.78	$73.65	$41.71	N/A	N/A
			Total		11	$ 16.38	$ 108.73	Sum of averages	$ 39.42	$73.65	$41.71	N/A	N/A
			Total*		13	$ 23.69	$ 100.00	Sample average	$ 47.62	-	-	N/A	N/A

Measure	READI Index ID	Cost Unit	Cost Type	Sample Data				Analysis		Results Benchmarks			
				Source	N	Min Price	Max Price	Type	Result	DEER08	DEER05	DEER01	Other
Water Heating													
Pipe Insulation (SHW)	100066, 100067	Per linear foot	Materials	DI contractors	4	$ 3.95	$ 11.74	Sample average	$ 8.98	$0.88	$0.37	N/A	#REF!
			Labor		3	$ 11.30	$ 15.00	Sample average	$ 13.77	$3.63	$2.44	N/A	#REF!
			Total		7	$ 15.25	$ 26.74	Sum of averages	$ 22.75	$4.51	$2.81	$2.33	#REF!
Pipe Insulation (steam)	100068, 100069, 100070, 100071	Per linear foot	Materials	DI contractors	2	$ 11.42	$ 12.94	Sample average	$ 12.18	N/A	N/A	N/A	#REF!
			Labor		2	$ -	$ -	Sample average	$ -	N/A	N/A	N/A	#REF!
			Total		2	$ 11.42	$ 12.94	Sum of averages	$ 12.18	N/A	N/A	N/A	#REF!
Lowflow Showerheads	100012, 100018, 100024, 100030	Per showerhead	Materials	DI contractors	9	$ 5.45	$ 29.22	Sample average	$ 18.50	$29.22	$22.95	$9.23	$29.63
			Labor		9	$ 5.72	$ 27.95	Sample average	$ 15.67	$16.74	$15.00	$10.77	N/A
			Total		9	$ 11.17	$ 57.17	Sum of averages	$ 34.17	$45.96	$37.95	$20.00	N/A
			Total*		13	$ 16.75	$ 48.00	Sample average	$ 34.91	-	-	N/A	N/A
Pool covers (nonres)	100004, 100005	Per square foot	Materials	DI contractors	9	$ 1.95	$ 2.60	Sample average	$ 2.20	N/A	N/A	N/A	N/A
			Materials+		16	$ 3.30	$ 16.81	Sample average	$ 8.31	N/A	N/A	N/A	N/A
Appliances & Electronics													
Network Power Management Software	100074	Per client PC	Materials	Vendors	9	$ 6.00	$ 33.00	Sample average	$ 17.07	N/A	N/A	N/A	$ 20.00
Ref/freezer Recycling (res)	15, 16, 10025, 10026, 10027, 10031-10033, 10071-10102	Per unit	Total	DI contractors	2	$ 72.00	$ 84.00	Sample average	$ 78.00	$77.13	$97.75	N/A	N/A
			Total (2+ units)		2	$ 36.00	$ 64.00	Sample average	$ 50.00	$77.13	$97.75	N/A	N/A
Ref/freezer Recycling (nonres)		Per unit	Total	DI contractors	2	$ 72.00	$ 84.00	Sample average	$ 78.00	$77.13	$97.75	N/A	N/A
			Total (2+ units)		16	$ 36.00	$ 64.00	Sample average	$ 46.56	$77.13	$97.75	N/A	N/A
Building Shell (Ag)													
IR film	19, 20, 21, 22, 100177	Per square foot	Materials	Distributors (4)	21	$ 0.085	$ 0.140	Baseline average	$ 0.113	N/A	N/A	N/A	N/A
			Materials		29	$ 0.118	$ 0.160	Measure average	$ 0.128	N/A	N/A	N/A	N/A
			Materials		50	N/A	N/A	Matched pair IMC	$ 0.020	N/A	N/A	N/A	N/A
			Materials*		50	N/A	N/A	Sample average IMC	$ 0.015	N/A	N/A	N/A	$ 0.021

Appendix G

Participation-Weighted Statewide Labor Rate Index

Table G-1: Statewide RSMeans Cost Indices Weighted by 2010-2012 HVAC Measure Claims

Climate Zone	Reference City	Material[1]	Installation[1]	Weights[2]	Weighted Material	Weighted Installation
1	Eureka	0.940	1.017	0.003	0.003	0.003
2	Santa Rosa	0.940	1.653	0.010	0.009	0.016
3	San Francisco	1.001	1.673	0.030	0.030	0.051
4	San Jose	1.000	1.448	0.015	0.015	0.022
5	San Luis Obispo	0.940	1.055	0.000	0.000	0.000
6	Santa Barbara	1.000	1.167	0.139	0.139	0.162
7	San Diego	1.000	1.152	0.047	0.047	0.054
8	Santa Ana	0.940	1.055	0.162	0.153	0.171
9	Los Angeles	1.001	1.167	0.218	0.218	0.255
10	Riverside	1.000	1.166	0.213	0.213	0.248
11	Redding	1.000	1.070	0.010	0.010	0.011
12	Sacramento	1.000	1.198	0.036	0.036	0.043
13	Fresno	1.001	1.113	0.022	0.022	0.024
14	Mojave	0.940	0.992	0.035	0.033	0.035
15	Palm Springs	0.940	1.054	0.047	0.044	0.050
16	Susanville	0.940	1.070	0.012	0.011	0.013
	Average	0.974	1.191	1.000	0.984	1.158

1 - Table 21, 22, 23 (Fire Suppression, Plumbing, & HVAC) RSMeans MasterFormat City Cost Indexes, Year 2013 National Average Base

2 - 2010-2012 Standard Program Tracking Data (all in-scope deemed HVAC claims)

Table G-2: Statewide RSMeans Cost Indices Weighted by 2010-2012 Lighting Measure Claims

Climate Zone	Reference City	Material[1]	Installation[1]	Weights[2]	Weighted Material	Weighted Installation
1	Eureka	1.002	1.146	0.005	0.005	0.006
2	Santa Rosa	0.965	1.187	0.013	0.013	0.016
3	San Francisco	1.061	1.571	0.049	0.052	0.076
4	San Jose	1.025	1.532	0.019	0.020	0.029
5	San Luis Obispo	0.904	0.962	0.005	0.005	0.005
6	Santa Barbara	0.894	1.097	0.134	0.120	0.147
7	San Diego	0.992	0.991	0.033	0.033	0.033
8	Santa Ana	0.962	1.030	0.192	0.185	0.198
9	Los Angeles	0.998	1.208	0.166	0.166	0.201
10	Riverside	0.925	1.065	0.200	0.185	0.213
11	Redding	0.997	1.018	0.011	0.011	0.011
12	Sacramento	1.012	1.133	0.038	0.039	0.044
13	Fresno	0.918	1.015	0.056	0.051	0.057
14	Mojave	0.904	0.964	0.048	0.043	0.046
15	Palm Springs	0.962	1.024	0.026	0.025	0.026
16	Susanville	1.001	1.018	0.005	0.005	0.005
	Average	0.970	1.123	1.000	0.956	1.112

1 - Table 26, 27, 3370 (Electrical, Communications, & Utilities) RSMeans MasterFormat City Cost Indexes, Year 2013 National Average Base

2 - 2010-2012 Standard Program Tracking Data (all in-scope deemed nonresidential lighting claims)

Table G-3: Statewide RSMeans Cost Indices Weighted by 2010-2012 Buidling Shell Measure Claims

Climate Zone	Reference City	Material[1]	Installation[1]	Weights[2]	Weighted Material	Weighted Installation
1	Eureka	1.041	1.137	0.001	0.001	0.001
2	Santa Rosa	1.004	1.335	0.021	0.021	0.028
3	San Francisco	1.095	1.381	0.097	0.106	0.134
4	San Jose	0.996	1.389	0.062	0.062	0.087
5	San Luis Obispo	1.009	1.141	0.001	0.001	0.001
6	Santa Barbara	1.002	1.170	0.072	0.073	0.085
7	San Diego	1.012	1.048	0.055	0.055	0.057
8	Santa Ana	1.000	1.175	0.112	0.112	0.132
9	Los Angeles	1.022	1.212	0.175	0.179	0.212
10	Riverside	1.002	1.212	0.156	0.156	0.189
11	Redding	1.036	1.157	0.038	0.039	0.043
12	Sacramento	1.163	1.225	0.103	0.119	0.126
13	Fresno	0.939	1.148	0.042	0.039	0.048
14	Mojave	1.000	1.087	0.013	0.013	0.014
15	Palm Springs	0.997	1.174	0.041	0.041	0.048
16	Susanville	1.041	1.157	0.011	0.011	0.012
	Average	1.022	1.197	1.000	1.030	1.218

1 - Table 07 (Thermal and Moisture Protection) RSMeans MasterFormat City Cost Indexes, Year 2013 National Average Base

2 - 2010-2012 Standard Program Tracking Data (all in-scope deemed nonresidential building shell claims)