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Statewide Codes and Standards Market Adoption and Noncompliance Rates

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1.   Executive Summary

For over thirty years, the California Energy Commission has worked to advance energy efficiency through promulgation of energy codes and standards for buildings and appliances known as Title 20 (appliances) and Title 24 (buildings). These standards are updated periodically to reflect the emergence of new energy-efficiency technologies and methods.

The California Statewide Codes and Standards Program (C&S Program, or Program) is implemented by the state's investor-owned utilities and seeks to improve energy efficiency by influencing the periodic updates to the Title 20 and Title 24 standards. A consortium of representatives from each of the investor-owned utilities, called the Stakeholder Review Committee (SRC), works to propose the updates and monitor changes in energy use and market trends as a result of the codes. The most recent round of updates to the standards went into effect in late 2005 for the building standards, and in the period 2006-2008 for the appliance standards.

Past studies have worked to estimate the energy savings attributable to the Program, but due to a lack of empirical data, have typically assigned estimated, place-holder values for three key influencing factors:

- Initial market penetration and naturally occurring market adoption

- Noncompliance rate for selected building measures

- Noncompliance rate for selected appliances

These parameters are key factors in the calculation of the savings attributed to the Program and are entries in the *Savings Estimate Spreadsheet* that was created by the Heschong Mahone Group, Inc.

The goal of the study, conducted by Quantec, LLC, was twofold: 1) to refine the original estimates made of noncompliance, initial market penetration, and naturally occurring market adoption rates by researching and analyzing the factors contributing to each parameter; and 2) to test the 2006 California Energy Efficiency Evaluation Protocols (Evaluation Protocols) as it applies to determining net savings resulting from Program activities. This study was *not* intended to be an evaluation of the Program and did not revise the gross savings estimates or any savings inputs into the Savings Estimate Spreadsheet other than those listed above. In addition, modifying the spreadsheet was not in the research scope.

Initial Market Penetration and Naturally-Occurring Market Adoption

In order to improve the Savings Estimate Spreadsheet's assessment of the energy impacts of the introduction of new Title 20 and 24 standards, this analysis was designed to research and establish refined estimates for:

1) The initial market penetration of appliances and building measures meeting the standards

2) The future market adoption trends of these items if the standards had not been implemented, i.e., the naturally-occurring market adoption rates

Research Methodology

Our approach for estimating both initial market penetration and naturally-occurring market adoption was to solicit expert opinions to estimate a market adoption curve, using a typical S-shaped curve. We chose the Bass model to approximate the process.

We used a unique approach to obtain expert judgment about the market adoption curve. An interactive web-based tool was created that allowed experts to use sliders moved by their mouse to input their selection of leading and following behavior and maximum market penetration parameters. They were able to view the adoption curve in real time and make adjustments until they were satisfied with its shape. The web tool was interactive in real time as it enabled the following:

1) Allowed the experts to see the shape of the diffusion into the market over time: As the expert moves the sliders that determine the values of the three needed parameters, (leading behavior, following behavior, and maximum market penetration), the curve starts to take shape on the screen.

2) Provided the expert with a verbal description of the selected shape: Once the expert decides the shape looks right, he or she clicks a selection button and a verbal description of the curve is displayed. For example, the description might be that the selected curve implies that the market penetration will never exceed 50%, current market penetration is at 20%, and the market is expected to take off in three years.

When the expert is satisfied with the shape and the verbal translation, the selection is submitted and the data are saved. All opinions are aggregated to produce the average S curve using a mathematical procedure that best fits the average values at each point. A second round allowed the participating experts to review the average curve, and provide feedback on the differences between their curve and the average. Based on this feedback and follow-ups with the participants, we finalized the naturally occurring market adoption curve.

A subset of the building measures and appliances covered by the new Title 24 and 20 standards was selected for analysis and these are shown in Table 1. This subset was selected primarily based on their contribution to total expected first year savings. The expected savings, number of experts targeted for this study, and number of experts who participated are shown in Table 1.

Table 1. Market Adoption Analysis Building Measures, Appliances, and Experts

Title 20 and 24 Measures and Appliances	First-year Savings, GWh Equivalent	Targeted Number of Experts		Number of Experts Participating
		Manufacturers/ Distributors	Contractors	
Hardwired lighting, new residential	65	-	8	3
Lighting controls under skylights, new	26	-	8	3
Duct improvement, residential existing	16	-	8	3
Ducts, nonresidential existing	19	-	8	
Consumer electronics-TVs	68	6	-	5
Consumer electronics-DVDs	12	6	-	4
Consumer electronics-audio players	53	6	-	4
Residential pool pumps, 2-speed, Tier II	130	6	6	7
Pulse start metal halides	49	6	-	7
General service incandescent	79	6	-	4
Commercial dishwasher spray valves	76	3	-	4
Unit heaters/duct furnaces	19	6	-	5

Results

Table 2 summarizes the results of these analyses. For each high efficiency measure and appliance, the table shows the year from which the adoption curve analysis starts, the 2006 estimated market penetration, and the estimated naturally-occurring market adoption rates for two representative years, 2015 and 2030. It is important to note that the estimates of market behavior presented in Table 2 stemmed from the informed opinions of a relatively small sample of industry experts. These data are qualitative in nature, and represent the best point estimates available at this time. Since a key objective of this study was to test the Evaluation Protocols, these results serve the dual purpose of providing improved Savings Estimate Spreadsheet estimates, as well as demonstrating the effectiveness of the chosen approach and offering key lessons for future research (as outlined below).

Table 2. Initial Market Penetration and Naturally Occurring Adoption Results

Title 20 and 24 Measures and Appliances	Market Introduction Year	Initial Market Penetration 2006, %	Naturally Occurring Market Adoption, %	
			2015	2030
Hardwired lighting, new residential	2000	8	35	56
Lighting controls under skylights, new	2000	7	38	51
Duct improvement, residential existing	1990	10	17	19
Ducts, nonresidential existing	1990	2	7	19
Consumer electronics-TVs	2000	41	76	83
Consumer electronics-DVDs	2000	24	58	61
Consumer electronics-audio players	2000	26	46	50
Res pool pumps, 2-speed, Tier II	1995	6	23	33
Pulse start metal halides	1992	26	46	57
General service incandescents[1]	1970	47	50	52
Commercial dishwasher spray valves	1985	25	41	51
Unit heaters/duct furnaces	1965	50	58	65

Building Standards Noncompliance

As with initial market penetration and naturally occurring market adoption, the development of the Savings Estimate Spreadsheet used placeholder values for building standards noncompliance rates; this value was 30% for all measures.

Research Methodology

Data were collected via a combined approach of reviewing building department records and conducting site visits at a sample of buildings to estimate the noncompliance rates. The building measures investigated are shown in Table 3.

Building departments were selected to represent a mix of projects and climate zones across the state (nine building departments in Arcata, Ceres, Elk Grove, Sonoma County, Paso Robles, Anaheim, Fullerton, Riverside County, and San Diego).

In total, 418 records were examined, representing 437 measures. Of those, a total of 395 measures had permits that were available for complete review.

Sample sizes were drawn with the goal of yielding statistically defensible results for each of the identified measures with 90% confidence ±10%. Actual precision levels ranged from ± 1% to ±10%.

Beyond the noncompliance values themselves, this study also provided valuable insight into the varying building department processes and procedures in place across the state.

Table 3. Building Measures Updated in Title 24

Measure	1st Year Savings (GWh)
Residential	
Hardwired lighting	64.6
Window replacement	6.3 (0.3 Mtherms)
Duct improvement	5.7 (1.1 Mtherms)
Nonresidential	
Lighting controls under skylights	25.5
Cool roofs	14.6
Bi-level lighting controls	12.1
Ducts in existing buildings	9.7 (1.0 Mtherms)
Duct testing/sealing in new buildings	8.0

Compliance Scoring

Each permit reviewed was given a score in each of three possible compliance categories: process, design, and field.

> *Process* reflects the completeness of the information contained in the permit file.

> *Design* represents the compliance level of the submitted blueprints or plans.

> *Field* corresponds to the observations made during the field inspections.

The scores themselves were derived from an evaluation of how close the component came to meeting the code requirement. Complete *noncompliance* existed when no evidence of knowledge or intent to comply with code existed (score =1). Partial compliance was given when some evidence was found of an attempt to comply with code, but compliance was incomplete (score = 0.5). Full compliance existed when the measure was present and was either fully documented, fully contained in the design or installed in the building (score = 0).

Determining Noncompliance Rates

During the permit review process, permit files were scored according to the system described above. These permit scores were used to obtain an *initial* estimate of compliance. Site visits were then carried out on a sample of buildings to assess the accuracy of the permit scores; the final site visit scores were then used to revise the initial compliance scores using a Bayesian statistical approach.

Results

Through this study, we found that *noncompliance* values varied widely by measure, ranging from 21% for hardwired lighting to 100% for nonresidential ducts (both new and retrofit). The noncompliance estimates for each measure studied are displayed in Table 4.

Table 4. Summary of Building Measure Noncompliance Estimates

Building Measure	Estimated Noncompliance rate	Precision of Estimate
Residential		
Hardwired lighting	28%	3%
Window replacement	68%	7%
Duct improvement	73%	1%
Nonresidential		
Lighting controls under skylights	44%	10%
Cool roofs	50%	3%
Bi-level lighting controls	n/a	n/a
Ducts in existing buildings	100%	2%
Duct testing/sealing in new buildings	100%	1%

We note that, since this study began shortly after the implementation of the updated 2005 building codes, utility-sponsored training and education (T&E) programs aimed at improving compliance rates had not been completed yet. These T&E efforts are carried out through IOU Energy Centers, the Savings by Design program, and statewide and local partnership programs. We expect that compliance with the 2005 standards will improve as these training efforts continue.

Appliance Standards Noncompliance

We assessed the noncompliance rates for nine appliance standards that went into effect in January 2006. The affected appliances were selected based on the magnitude of their estimated energy savings.

Appliance manufacturers are required to submit an application to the California Energy Commission (CEC) to have their product certified as meeting Title 20. For appliances manufactured after the effective date of these standards, only those certified can be sold legally in California. The CEC maintains a database listing the certified appliances of each type. The appliances included in our study and a description of the Title 20 energy-efficiency requirements are provided in Table 5. The table also indicates whether or not the appliance type was in the CEC compliance database when we conducted our study.

Table 5. Appliance Standards Included in Noncompliance Analysis

Appliance Category	In CEC Database	Standard
Televisions	Yes	Max. standby power usage =3W
DVD Players	Yes	Max. standby power usage =3W
Residential Pool Pumps, Tier 1	No	Motor may not be split phase or capacitor start-induction run type motor
General Service Incandescent, Tier 1	No	Max. wattage set for lumen output; applies to most incandescent and halogen lamps between 25 and 150 watts. Rough service, decorative, 3-way, and colored lamps are excluded. Frost/clear: Max. W=(0.05*lumens)+21 Soft white: Max. W=(0.05*lumens)+22.5
Metal Halide Luminaires	No	Allows only pulse-start ballasts for vertical lamps with base up applications. Probe-start ballasts disallowed.
Walk-in Refrigerators/ Freezers	No	Usually custom made. Requires automatic closers on doors <4' wide and <7' high; R-28 insulation in refrigerators, R-36 in freezers; electronically commutated, permanent split capacitor type, or polyphase motors on condenser fans <1 HP; electronically commutated or permanent split capacitor type motors on evaporator fans <1 HP.
Pre-rinse Spray Valves	No	Flow rate ≤1.6 gpm @ 60 psi; cleans 60 plates at average of ≤30 seconds per plate.
Unit Heaters and Duct Furnaces	Yes	Natural gas-fired unit heaters and duct furnaces shall have either power venting or an automatic flue damper | Type	Fuel	Min. Efficiency @ Max. Capacity	Max. Watts during Standby
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Duct furnaces	Nat gas	80	10
Duct furnaces	LPG	80	147
Unit heaters	Nat gas	80	10
Unit heaters	LPG	80	147
Unit heaters	Oil	81	N/A	
Refrigerated Canned/Bottled Beverage Vending Machines	Yes	Max daily kWh=0.55*(8.66+(0.009*C)); C=rated capacity, # of 12 oz. cans

Methodology

Our primary approach to estimate noncompliance rates was to identify a sample of retailers and/or wholesalers for each appliance and conduct site visits to collect primary data on brands/models sold and their sales volumes. Our basic approach was to determine whether each brand/model complied with Title 20 and, using the sales volumes, calculate the overall noncompliance rate.

In addition to collecting information from wholesalers/retailers, we contacted distributors and manufacturers of each appliance and obtained relevant information from websites and requested and reviewed catalogs. A stratified cluster sampling approach was used to select retailers and wholesalers for site visits.

The site visits were conducted between July 26 and September 11, 2006, by Quantec field technicians. They began in Southern California and moved north.

The site-visit data were analyzed to determine which models at each outlet did or did not comply with the relevant California standard. We also intended to determine which models were manufactured prior to the effective date of the standards, but this was not possible since we found that manufacture dates were not provided for the products. The primary source of compliance information was the CEC databases of certified products. The noncompliance rate for each appliance was then estimated based on the rate for each outlet, approximate sales, and appropriate weights for the strata.

This general approach had to be tailored to each appliance. In the early stages of data collection, it was found that CEC certification databases existed for only four of the appliances studied. Instead of categorizing all these units as "not in compliance," a decision was reached to assess compliance of the products sold using supplemental information.

Results

Our estimates of noncompliance rates for each appliance are presented in Table 6. *Noncompliance* varied from virtually zero (all units complied) to 63%. The average noncompliance rate across all these appliances was 32%.

Table 6. Summary of Noncompliance Estimates for 2006

Appliance Category	Estimated noncompliance rate	Certainty level of estimate
Televisions	41%	Medium
DVD Players	57%	Medium
Residential Pool Pumps, Tier 1	15%	Medium
General Service Incandescents, Tier 1	27%	Medium
Metal Halide Luminaires	37%	Low
Walk-in Refrigerators/ Freezers	0%	Medium
Pre-rinse Spray Valves	4.2%	High
Unit Heaters and Duct Furnaces	44%	Low
Refrigerated Canned/Bottled Beverage Vending Machines	63%	Low

Lessons and Recommendations

Initial Penetration and Naturally-Occurring Market Adoption

The methodology used in this study to research naturally-occurring market adoption rates was a pioneering effort, and yielded a number of key lessons on how this process could be improved in future applications.

- Experts should be identified during the standards development process and they should be informed that their input will be required to estimate market trends.

- The amount of the incentive should be increased to an adequate level, as we found that $100 was inadequate to incentivize responses.

- Empirical data on the baseline market should be developed, and then used to provide an anchor point for the experts who will participate in the market estimation exercise.

- The process should be expanded to fully implement the Delphi approach by conducting one or two additional rounds to allow the respondents a chance to revise their estimates and exchange information on the range of estimates.

Building Standards Noncompliance

In order to pinpoint and correct flaws in the compliance chain so that energy savings predicted from the codes can be fully realized, we propose future research in the following areas:

- Conduct building surveys to determine the frequency of permitted vs. nonpermitted construction projects by measure and by jurisdiction to learn more about the penetration levels of the codes and standards.

- Identify existing building department processes and ensure that compliance and other implementation forms fit into these processes.

- Survey building industry professionals to identify barriers that may exist in implementing and complying with energy efficiency building codes. This information would be valuable in the design of training and educational efforts, as well as in the design of future code updates.

- Conduct studies on building performance. These studies characterize the market in a more complete way than do measure-specific studies, and allow more accurate predictions into the benefits of codes and standards, and the impact of enforcement.

Appliance Standards Noncompliance

The following lessons learned and recommendations were developed as a result of our research:

- When noncompliance is researched shortly after a standard goes into effect, special issues may arise that need to be addressed in the research approach and scope. Specifically, if databases are not available for identifying complying products then the approach and scope should be designed to implement other research that may be necessary to determine compliance.

- There are likely to be limitations in the accuracy of databases used to identify vendors for data collection site visits so it is important to verify during pre-site visit calls that vendors are correctly classified and carry the proper product. In addition, it is important to have the flexibility in the field to identify other vendors that can provide information.

- Special steps should be taken to enlist the cooperation of retailers and wholesalers including presenting a letter from the state or utility explaining the study and contacting corporate management to have them notify the local vendor that they have approved the site visit.