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Mercury-Containing Thermostats: Estimating Inventory and Flow from Existing Residential & Commercial Buildings

A Study to Meet Requirements for State of California Thermostat Recycling Legislation

prepared for:
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1. Project Background and Executive Summary

The State of California will develop regulations establishing collection rates for waste mercury-containing thermostats. As part of the planning process, the State mandated that thermostat manufacturers develop a "statistically valid" estimate of the mercury-containing thermostats that annually become waste in California.

To develop the required estimates, the Thermostat Recycling Corporation, acting on behalf of 28 manufacturers that historically sold mercury-containing thermostats, contracted with Skumatz Economic Research Associates (SERA) of Superior Colorado, experts in energy- and recycling-related surveys, statistics, and estimation of measure lifetimes and "decay curves". The project's activities included:

- Developed technical approach for the project for review by the State and Stakeholders that could fulfill the mandates of being methodologically defensible
- Discussed the technical approach at a meeting in Sacramento, and responded to questions
- Developed a web survey including the key questions needed to develop estimates required by the legislation
- Designed appropriate sampling designs to "represent" the desired population, and purchased lists of random households, and stratified random sample of businesses, across the State
- Prepared tailored postcards inviting the residential and commercial samples to complete the survey on-line (phone number also provided for those wishing to complete via phone)
- Mailed a second postcard and conducted pro-active telephone surveys with the commercial sector to improve the statistical properties and increase the response count
- Analyzed the data gathered from the survey;
- Conducted two validation survey efforts – on-sites to 30 respondent premises to verify accuracy of the survey responses on thermostat type and to provide indicative information on the presence of mercury in ambiguous thermostat types (round, square, etc.). We also sent disposable cameras to 44 respondents to provide an additional opportunity to verify the accuracy and consistency of responses regarding reporting of thermostat "counts" and types.
- Prepared a draft report (and final report incorporating comments), to be completed by the end of December 2009.

The analysis shows that there are an average of 5.6 total thermostats in the average business premise (businesses, not buildings, were the unit of measure). The average household in the State of California has 1.2 thermostats. Although we cannot accurately project the share of these total thermostats that are mercury-containing (the study's focus was inventory and flow), it was possible to develop a range. The "high" end of the range derives from an assumption that 100% of any thermostat type that *can* contain mercury *does* contain mercury. The outcome of this assumption is that all thermostats except digital models are assumed to contain mercury – an obvious overestimate, but the estimate provides a "bound". The "lower" estimate derives from a small sample of site visits, during which an inspector popped the lid off all except digital thermostats. A significant number of potentially-mercury-containing thermostats instead used bimetal strips or were otherwise non-mercury versions of the models. The use of this figure reduces the mercury-containing shares for square and round models to 17% and 70%,

respectively. Using these sources, the computed range for the share of thermostats that contain mercury varies between 22-46% for commercial and 27-47% for residential models currently in-the-field.

Tables 1.1- 1.5 summarize the results of the study. Our research indicates that:

- There are about 1.4 million mercury-containing thermostats in the commercial sector (taking the midpoint of the high / low ranges); and about 5.8 million mercury-containing thermostats in California households, for a total of about 7.2 million (5.1-9.3 million) mercury-containing thermostats statewide.
- Our mid-point estimate is that there are 0.4 mercury-containing thermostats per household (1.2 total thermostats), and 1.9 mercury-continuing thermostats per business (of 5.6 total thermostats per business.
- The penetration of digital thermostats in the State is about 53-54% in both the commercial and residential sectors.

Validation Analysis: Although not part of the legislative requirements, we conducted two small-scale validation efforts to provide indicative data on the reliability of self-report data for a study of this nature. We conducted 30 site visits centered around the Bay Area, and in a separate effort, we mailed out 44 disposable cameras to a random sample of respondents state-wide. A detailed description of the results and methods is found in Section 4.1 of this report. The camera validation work was still in progress at the time this report was prepared, so fewer replies from that approach are available (12 returns).

The combination of these two validation efforts finds that self-reports were correct in the majority of cases. There were a total of five errors in the reported totals of thermostats on the premise from the 42 validated sites (12% had errors); the errors in "total count" were 4% from the residential side, and 15% from the commercial side. Using these figures, we find a total estimated weighted correction factor (given the total thermostats reported from the residential vs. commercial sectors) of about 13.5% undercounting of thermostats using self-reported figures. The validation work also examined the accuracy in the report of types of thermostats present in the home or business. No errors were detected in the photo sample; four residents and no businesses reported incorrect types based on the on-site validation work (3% error in types compared to the total thermostats inspected). These results are included in Table 1.6.

Survey Feedback – "Drivers" and Intervention Points

Finally, we gathered information on the drivers, or possible intervention points for capturing the mercury thermostats.

- Business Thermostat Replacement Drivers and Disposal Practices:
    - The number two reason for replacing the thermostat is proactive switch-out for a programmable model. The other drivers for business replacement / removal of thermostats are renovations / replacement of the heating system, and a thermostat that stops functioning. Some heating / cooling system upgrades do take place without replacing the thermostats, but these are a minority (about 1/3 as often as replacing the thermostats).
    - The single most important influencing factor for removing the wall thermostat was to replace it with a model or system that would allow better and more even temperature control, followed closely by a move to a more efficient heating system.

- Most businesses have taken little responsibility for the disposal of removed wall thermostats. The vast majority said they "didn't know" what happened to them, or the contractor disposed of it and the business didn't know where. A small minority said they were disposed in trash and about the same number indicated it went to a recycling facility.
- Note that about 5% of the responding businesses indicated there is a small cache of removed and used thermostats awaiting discard or recycling at their facility. These would be likely to be brought forward in the initial years of any convenient thermostat recycling program that might be established.

- Residential Thermostat Replacement Drivers and Disposal Practices:
  - Households show similar patterns in drivers for replacement of thermostats: upgrades of the heating / cooling system, followed with a very close second of a desire to install programmable thermostat.
  - In the residential sector, the existing thermostats were retained after a heating / cooling system upgrade only about one-fifth of the time.
  - Influencing factors for replacement included the desire for a more even temperature in the home, and an upgrade to a more energy efficient heating system. Utility energy programs and rebates were an important, but lower tier, driver (about half as important as the system's efficiency). The utility incentives were about equal in importance with high heating / cooling bills and the addition of new space in the home as a driver.
  - The vast majority of households say the contractor disposed of the removed thermostat equipment and they do not know what was done with them; many others don't know at all what happened to the removed equipment, or said they threw them in the trash. Another 5% said they still have old ones in storage (which may result in a small surge at start-up of a new program), and a similar number said they were delivered to a recycling center.
  - The level of planned remodels in businesses or homes that may potentially affect thermostats is fairly low over the next three years, presumably due in part to the economy.

Beyond the "count" information provided in Tables 1.1-1.5, the key lessons learned from this research are:

- Nearly half the respondents (47% of households, 40% commercial) were completely unaware that older thermostats could contain mercury. Neither households nor businesses think at all about recycling or potentially proper disposal of thermostats.[1] Contractors were the leading reported destination for removed residential and commercial thermostats. *The vast majority of thermostats can be recovered by acting on the primary contractors who are responsible for the majority of retrofits for both the residential and commercial sectors*. *"Do it yourself" efforts seem a relatively small part of the market and cause of thermostat disposal.*
- The low response to our first round of postcards requesting participation in the survey *demonstrated a relative disinterest in mercury thermostats as a special disposal issue.*

[1] Two-thirds of households with a thermostat replacement said the contractor disposed of the thermostat and they didn't know where, or they just didn't know where the removed thermostat(s) went. Only about 5% reported sending them to an appropriate facility. Commercial respondents were even less likely to know where the thermostats went and relied on contractors. Contractors were 3-4 times more commonly-cited as a thermostat destination than any other listed (hazardous waste site, trash, used in other locations, etc.).

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When we sent the second email, we portrayed the survey as one addressing general recycling and "hard-to-recycle" items (and we added a few general questions to draw them in before hitting them with our thermostat queries). Residents and businesses are not tuned into thermostats.

The remainder of this report focuses solely on methods and the estimation work. There are no additional results related to the central goal of the project are included in the remainder of the report.

Table 1.1: Summary of Key Results on the Inventory and Flows of Mercury-Containing Thermostats in Businesses and Households in the State of California (source: project survey, or directly-resulting computations, unless otherwise noted)

Average (and 95% confidence interval)	Commercial	Residential	Weighted Average
Avg Thermostats per business, Household, est.	5.6[2] (-0.22-11.39)	1.17[3] (1.1-1.2)	1.5 (.44-2.6)
Total Thermostat shares, California, estimated	21%	79%	100%
Total Thermostats in California, estimated	4.1 million	15.7 million	19.8 million
Share that are mercury-containing, lower, est.*	22%	27%	26%
Share that are mercury-containing, high, est.*	46%	47%	47%
Total Mercury-containing, Lower, est.	0.9 million	4.2 million	5.1 million
Total Mercury-containing, high, est., (parentheses incorporate higher estimate adding 13.5% for possible underreporting identified in validation	1.9 million (2.2 million)	7.4 million (8.4 million)	9.3 million (10.5 million)
Average Age in years, all	15.7 (14.9-16.4)	11.7 (10.9-12.5)	12.56 (12.0-13.1)
Average Age in years, square	21.9 (20.8-23.0)	21.4 (19.2-23.6)	21.6 (20.3-22.8)
Average Age in years, round	29.4 (25.5-33.3)	30.9 (27.0-34.8)	30.5 (27.8-33.2)
Average Age in years, digital	8.5 (7.9-9.1)	6.3 (5.9-6.8)	6.8 (6.4-7.1)
Average Age in years, snap	18.8 (15.2-22.4)	11.7 (8.3-15.1)	12.4 (9.8-15.0)
Average Age in years, lever	31.2 (28.5-33.8)	14.2 (9.8-18.7)	17.5 (14.4-20.7)
Average Age in years, other	12.1 (6.1-18.1)	25.0 (15.4-34.7)	20.4 (15.9-25.0)
Est. Number of households and businesses in California (Source: Census 2006, 2008)	723,900[4]	13.4 million	14.1 million

Note(*): "lower estimate" for mercury-containing thermostats derived from very small (30 observations) on-site validation survey. "High estimate" derived from "worst case assumptions" where only digital thermostats are assumed to lack mercury. The actual share of mercury models will be less than worst case, but may be higher or lower than "lower" estimate.

[2] This translates to an average of approximately 0.3 thermostats per paid employee in California. 90% confidence band presented for the commercial mean (smaller sample); pr>t at 95%=0.16. The figures presented are weighted by business size (employment categories, commercial) and housing units (by single-family detached, attached, and categories of multi-family sizes for residential).

[3] The average percent reported to be "working" was 94% in commercial business, and 93% in homes.

[4] These are 723,880 businesses listed under "all firms" with employees from "US Census Bureau Statistics of US Businesses 2006: All Industries, CA". There are apparently a high number of non-employee businesses in the State. Census bureau "Quick Facts" shows "all firms" to be 2.9 million in California in 2002, and private non-farm firms as 892,000 ("establishments" in Census "US Businesses" is 878.128). "All firms" would imply figures almost exactly four times as high in the commercial sector; scaling to "establishments" would increase commercial figures by 20%. We sampled from businesses with 1 or more employees.

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Table 1.2: Percent of Thermostats by Type

Percent of thermostats by type, estimated from survey; mean (95% confidence band)	Commercial	Residential	Weighted Average
Square	25.5% (19.6-31.5%)	20.7% (17.6-23.8%)	21.0% (18.4-23.7%)
Round	9.1% (5.4-12.9%)	8.7% (6.8-10.7%)	8.7% (7.0-10.4%)
Digital	53.6% (46.9-60.4%)	53.4% (49.6-57.2%)	53.4% (50.0-56.7%)
Snap	3.8% (1.8-5.7%)	9.2% (7.2%-11.3%)	8.8% (7.1-10.6%)
Lever	5.6% (2.5-8.5%)	5.3% (3.8-6.8%)	5.3% (4.0-6.7%)
Other	2.4% (0.6-6.8%)	2.6% (1.9-3.4%)	2.6% (1.9-3.3%)
Total	100%	100%	100%

Table 1.3: Average Age of Thermostats by Type

Average Age of Thermostats, in years. Average (95% confidence interval)	Commercial		Single Family		Weighted Average	
Square	21.9	(20.8-23.0)	21.4	(19.2-23.6)	21.6	(20.3-22.8)
Round	29.4	(25.5-33.3)	30.9	(27.0-34.8)	30.5	(27.8-33.2)
Digital	8.5	(7.9-8.1)	6.3	(5.9-6.8)	6.7	(6.4-7.1)
Snap	18.8	(15.2-22.4)	11.7	(8.3-15.1)	12.4	(9.8-15.0)
Lever	31.2	(28.5-33.8)	14.2	(9.8-18.7)	17.5	(14.3-20.7)
Other	12.1	(6.1-18.0)	25.0	(15.4-34.7)	20.4	(15.9-25.0)
Overall	15.7	(14.9-16.4)	11.7	(10.9-12.5)	12.7	(12.0-13.1)

Table 1.4: Percent of Models Containing Mercury, by Type – "Worst" Case vs. Validation Percentages[5]

Range for Percent with Mercury, by type, estimated	Lower (Source: site visit)	High ("Worst" Case)
Square	17%	100%
Round	70%	100%
Digital	0%	0%
Snap	100%	100%
Lever	100%	100%
Other	100%	100%
"Worst case" assumes any thermostat type that CAN have mercury, contains mercury. Low case based on Validation survey. Note Site visit includes only 30 on-sites / small sample.		

[5] Note that these figures were not derived from the survey respondents, as they were only asked to identify broad "types" as listed below. The percent mercury figures were from a small-sample audit / site visit of 30 respondents (column1) and "worst case" assignments of model visual "types" that, at an early generation of manufacture and internal design, could ever have contained mercury.

Table 1.5: Anticipated Flow of Mercury-Containing Thermostats by Year (using Low and High Mercury Model Saturations from Table 1.4 and Decay model described in Section 4.5)[6]

Year	Annual Flow of Mercury-Containing Thermostats - Low Estimate (5.1 million total Hg Thermostats), estimated.	Annual Flow of Mercury-Containing Thermostats - High estimate (9.3 million total Hg Thermostats), estimated.	Annual Flow of Mercury-Containing Thermostats - High estimate (10.5 million total Hg Thermostats), adding 13.5% validation premium
1	237,000	432,000	490,000
2	233,000	425,000	482,000
3	222,000	405,000	460,000
4	217,000	396,000	449,000
5	212,000	387,000	439,000
6	207,000	377,500	428,000
7	202,000	368,000	418,000
8	197,000	360,000	409,000
9	193,000	351,000	398,000
10	187,000	340,000	386,000
11	181,000	329,000	373,000
12	174,000	318,000	361,000
13	168,000	308,000	350,000
14	162,000	298,000	338,000
15	156,000	288,000	327,000
16	150,000	279,000	317,000
17	144,000	270,000	306,000
18	137,000	261,000	296,000
19	131,000	253,000	287,000
20	129,000	235,000	267,000
21	127,000	232,000	263,000
22	113,000	207,000	235,000
23	103,000	187,000	212,000
24	94,000	172,000	195,000
25	99,000	181,000	205,000
Total estimated mercury thermostat flows during 25 years	4,175,000	7,659,500	8,694,000
Total to be recovered (installed in CA)	5,100,000	9,300,000	10,556,000
Total for first 25 years as share of total to be recovered (assumes no new mercury thermostats may be installed)	82%	82%	82%

[6] To represent a "high" high estimate, the estimates could be further adjusted using confidence intervals from Appendix B.

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Table 1.6: Response Totals and Validation Study Visits

	Commercial	Residential	Total
Survey Responses			
Number of survey responses	267	595	862
Number of thermostats covered	4386	690	5076
On-site Validation			
Validation visits (and percent of survey responses)	5 (1.9%)	25 (4.2%)	30 (3.5%)
Reported Thermostats covered by validation (and percent)	45 (1.0%)	36 (5.2%)	81 (1.6%)
Validation Thermostats count (validated & pct diff)	53 (18% extra)	37 (2.8% extra)	90 (11% extra)
Camera Validation			
Cameras Sent Out	7	37	44
Returns (as of 12/28/09)	3	9	12
Reported Thermostats covered by validation	14	11	25
Validated Thermostat count (validated & percent diff)	15 (7% extra)	12 (9% extra)	27 (8% extra)
Overall Thermostat "Count" Correction Factor (Based on Total Validation Responses) (raw, and weighted for total)	68 (15% extra)	49 (4% extra)	117 (10% extra) (13.5% extra weighted avg)
Overall error in thermostat "Type" reporting	0%	8%	3.4% of all thermostats inspected

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2. Introduction to the Project

A number of states are passing mandatory mercury thermostat collection laws and associated collection goals. However, the goals are imperfectly set, as information on the number of mercury thermostats, in either commercial or residential buildings, is largely unknown. Developing targets, planning for handling and diversion/ disposal, and investing in the design of programs are all improved with more reliable information on the inventory of mercury thermostat, their removal rates and practices, and the actors involved.

With the exception of one statistical study (King County, commercial sector) most of the goals were set using "rules of thumb" or very crude assumptions. For example, the State of Iowa asserts an assumption that each home has 1.25 thermostats for its draft goal-setting computations.

The State of California requires delivery of a "study" that provides estimates of the number of thermostats potentially available for disposal / recycling / management. This chapter describes the approach we used to produce high quality, defensible estimates of:

- The inventory or "count" of thermostats in place in California households and businesses; and
- The annual "flow" of this equipment out of the buildings, potentially subject to capture through a thermostat recycling program.

Our approach used a large-scale web survey to identify the "saturation" of mercury thermostats, and we used statistical analysis methods to estimate the decay function for thermostats. Our approach adapted and streamlined some of the King County methods, and incorporated energy efficiency estimation approaches to provide reliable estimates of the following information:

- Number of mercury thermostats in place in residential buildings and separately in commercial buildings - useful for an inventory and to predict the lifetime flows of equipment;
- Number of annual removals of mercury thermostats from residential and commercial buildings (separately) – useful for setting annual goals;
- Practices in removing thermostats (and destinations), actors involved in decision-making and removal, and factors influencing removal rates in commercial vs. residential buildings – useful for identifying intervention points, possible program / capture designs to most effective (and cost-effectively) redirect the equipment to proper disposal, etc.

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3. Collecting the Data: The Residential / Commercial Thermostat Survey

There are four key elements to strong survey data collection, each of which is addressed in the paragraphs below.

- A sampling frame that well-represents the population (i.e. a good sample source),
- Good sample design that incorporates a prior information about possible patterns in responses and data,
- Responses from a random set of the selected sample, and
- Accurate and thorough data from the respondents.

3.1 Selecting the Samples

Surveys are useful methods for gathering data representative of populations. In our case, the populations were defined as California businesses and households. Statistics make it clear that it is not necessary to interview or visit every building in order to get accurate estimates of the number of thermostats in these buildings. Instead, once data from a certain threshold number of respondents are reached, there are significantly diminishing returns from additional data, allowing affordable data collection.

Sample Source: We used one of the most highly-respected firms from which to purchase the necessary contact data – InfoUSA. This firm is the source for data for Gallup-type polls, as well as thousands of universities and research firms across the nation. They were the source for both our residential and commercial data, and we have used the firm for many previous research projects.

Sampling design: We used both simple random and stratified random sampling designs to develop our samples, using the lists purchased from InfoUSA. The approaches for the residential and commercial sectors are presented below.

- **Residential**: We used a simple random selection process to select the sampled home addresses from our purchased sample. The project's design was to households in California in its entirety, so there was not stratification used by geography, age of home, or home type (single-family vs. multi-family).

- **Commercial**: The best stratification methods for the commercial sector almost always include size (square footage or employment).[7] We used employment as the stratification variable for this survey, largely because employment categories are well-reported in census, allowing us to compare response proportions to that independent source to identify whether troublesome non-random patterns in responses occurred in our survey. Distributions of businesses (or buildings) by size are far from even. There are many more small firms / buildings than large ones, but energy use and square footage covered (and in a related

[7] The remainder of this discussion assumes that the commercial survey entity is a business, not a building. If we can identify a source for "building" addresses with an associated respondent firm, we can substitute that if desired.

manner, the number of thermostats[8]) would be disproportionately higher in (the fewer number of) large firms. Generally, if there is any reason to believe that there are differences in the responses from large vs. small buildings (in thermostats, in response rates, in decision-making or other topics of our analysis, or if we want to be able to present information separately by size or building) it is important to assure there are reasonable response numbers from these large buildings. Thus, we used a "stratified random" design, and we sent out a larger proportion (but not necessarily larger total number) of postcards to this group. This stratification technique can improve the quality and robustness of the database. Because small buildings or businesses tend to be more homogeneous, a smaller percent (although still large number) of respondents can be included in the sample. This kind of stratification increases the response from large businesses (and presumably larger buildings) which would likely include more thermostats and increase the explanatory power for estimating the number of thermostats across the State.

Sample Size: It is natural to assume that that sample size is directly related to "coverage" of the survey – that is, one might think many more surveys would be needed to represent a State as opposed to representing a city. Actually, that is not true, and is illustrated in the table below. The number of responses needed to represent a city of 10,000 and a state of 10,000,000 at +/-5% accuracy with 95% confidence[9] is not very different (on the order of 380 responses). No matter how big the total households (within a fairly large band), the sample sizes needed are similar.[10] Regarding the question of how many surveys it takes to achieve higher levels of accuracy, statistical sample sizes are far from proportional; double the accuracy requires more than twice the sample (almost four times – increasing from 96 to 384).

Table 3.1: Computation of Sample Sizes and resulting accuracy / confidence levels

IF the population (homes or comm'l bldgs) is…	95% confidence		90% confidence	
Computed responses needed for accuracy of…	+/-5%	+/-10%[11]	+/-5%	+/-10%
100	79	49	73	40
1,000	278	88	213	63
10,000	370	95	263	67
100,000	383	96	270	68
1,000,000	384	96	271	68
10,000,000	384	96	271	68

Our mailings were designed to obtain between 270 and 380 responses for each of the residential and commercial sector. Given there are about 724,000 businesses and more than 13 million households in California, these figures would provide confidence in certain survey data at levels of +/-5% at the 90% and 95% confidence levels, respectively. To achieve these responses we selected samples of 12,000 businesses and 10,000 residences (businesses have a lower response rate). Our commercial sample oversampled among the larger business sizes. Our final responses reached or exceeded goals (594 residential, 267 commercial, Table 4.1).

[8] Although the information from the King County study indicates otherwise – they did not find significantly more thermostats in large buildings; however, it is important to identify whether this finding is corroborated.

[9] The statement of confidence level is standard practice; however, it is simplified and slightly misleading. It states the accuracy with which you would predict a 50% response (e.g. male / female, yes/no) given random responses totaling the number given from the sample, compared to the answer from the population. It does not predict the accuracy of an answer of, say, "9" from among a number of categories, etc. However, it serves as a benchmark for higher vs. lower accuracy sample sizes.

[10] This is why Nielsen television ratings or Gallup election polls can use nationwide samples of 1200 and get accuracy nationwide.

[11] Also approximately equal to +/- 7% at 90% confidence.

3.2 Contacting the Sample

Postcard outreach to web survey: We issued quarter-page size postcards[12] to samples of the residential (single- and multi-family combined) and commercial sectors; providing a link to a web survey and requesting their participation. We also let them know that filling out the survey entered the respondent into a lottery to win one of several MP3 players[13] or gift certificates. We posted the survey link on a neutral website ("www.garbageandrecyclingsurveys.org" , which SERA owns) Participants navigated to the website and clicked on the labeled button to launch the survey.

To allow flexibility, we also provided a toll-free number on the postcard and administered the survey via phone to anyone preferring that option. To increase response and reduce bias, we used a two-stage method, sending an initial postcard, and then several weeks later, a reminder postcard.[14] In an unusual result, we received significantly higher responses rates to the second postcard, as it eliminated the focus on thermostats and portrayed the survey as soliciting feedback on "Recycling and Hard-to-Recycle" programs. As one final adjustment, to make sure we had strong response from large businesses (who potentially had large numbers of thermostats), we called these sample elements and conducted phone interviews with more than 30 of these businesses and incorporated them into the database.

3.3 The Questionnaire

SERA has conducted more than 100 large-scale surveys for both residential and commercial energy-related equipment inventories and similar studies. Over time, our techniques have evolved. Originally we used paper surveys, then phone surveys, and most recently, we have found that web surveys are a very effective and efficient strategy, especially for a project with an aggressive time line and one that needs photographs, like this one. A web survey provides several advantages.

- Inexpensive and very speedy data collection
- Respondents can fill out the survey night or day – at their convenience – which turns out to be especially convenient for businesses;
- Skip patterns are automatic - so errors do not arise and the survey can be shorter or longer based on specific responses;
- Drawings / pictures can be incorporated for clarification of issues –this was very important for this survey, as we needed to incorporate photographs of various thermostat types;
- Data is automatically entered into the computer – no separate keypunch entry costs (and errors).

On-going data checking – we can look at responses after the first few and make adjustments to the survey to correct for anything that seems unclear or to probe on issues. The data can be analyzed in "real time" and the survey "left active" and analyzed again when more responses have been received

[12] The first round of postcards was black print on colored card stock; the follow-up postcard was colored on white card-stock.
[13] We have found this prize works amazingly well for both the residential and commercial sector. The cost of even several dozen MP3 players is still many times less than the cost of a large scale phone survey (other options include gift certificates, checks, and other options). We have gotten strong response rates from this approach, and the bias from web access may not be dramatically different from problems introduced in phone surveys from unlisted numbers and cell phone only households.
[14] An adaptation of the "Dillman" method for reducing survey bias.

We used skip patterns embedded in the survey so questions appropriate for single family residential vs. multi-family residential vs. commercial respondents can answer appropriate questions.

Questionnaire content: The survey was designed to gather data on 1) key analytical data of interest, and 2) demographics or "firm-o-graphics" that allow us to identify whether there is potentially bias in responses. This supporting data must be asked in a way that allows us to match response proportions against the initial sampling frame database or against published "census" or other data. The following question topics were included in our web survey.

- Whether there are any thermostats in building
- Type of thermostat: We included photos of various types, and asked respondents to classify thermostats into square, round, digital, snap, other digital, others with levers or similar, or other (their description). These were the key types provided by the Thermostat Recycling Corporation and their members (along with photos), and could be used to help classify thermostats into mercury-containing or not, since it was decided not to have survey respondents pull the covers from thermostats to identify whether they contained mercury.[15]
- How many thermostats in building of the type(s) of interest; whether each is still functioning (&)[16]
- Year built (*); year thermostats installed (&)
- Year remodeled (*); year remodeled that removed / involved thermostat (&); reason for removal for any thermostats removed (&);; Expected timing of next remodel / next remodel involving thermostat
- Square feet(*)
- Predominate use of the building(*)
- Heating fuel type(s)
- Who removed the thermostat; destination of removed thermostats, actors involved in decision-making and removal
- Factors influencing remodeling and thermostat removal rates (in commercial buildings especially)
- Other information useful for identifying intervention points, possible program / capture designs to most effectively (and cost-effectively) redirect the equipment to proper disposal, etc.
- Demographic data: type of home (SF detached, attached, MF, etc.); number of residents, square footage, number of bed and bath rooms (predictor for square footage); education of head of household and/or income; zip code[17], and County;
- Firmographic data: type of business, main activity at the site; single firm or chain / central decision-making, square footage, number of employees, single or multiple occupants in building, other.

[15] These extra efforts might also have negatively affected survey response rates.

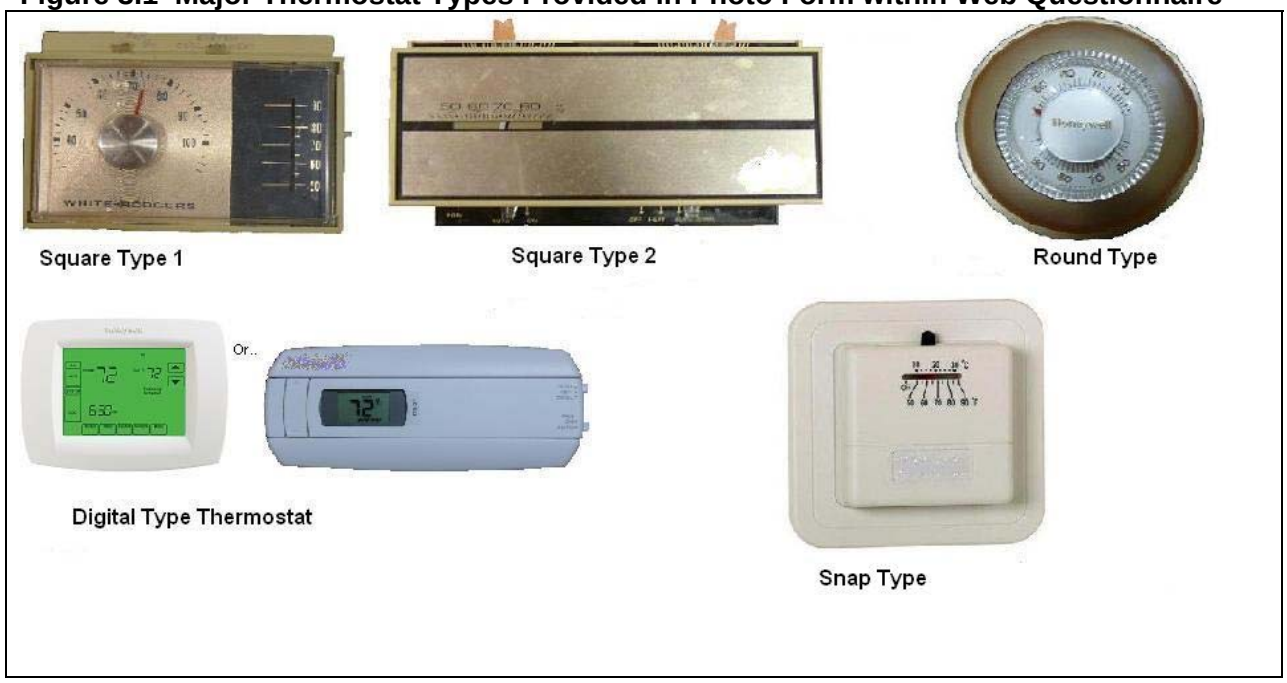
[16] The group of 4 features marked with asterisks (*) were identified as strong explanatory factors for the King County work. The group of data collection elements marked with ampersands (&) represents potentially useful data related to measure retention / removal / decision-making analyses.

[17] Zip codes and / or counties provide the opportunity to check for geographic bias in the results (by comparing to census data to check for representativeness of the responses). Weights based on county responses and on within sector responses were used to improve the representation, and were used in the derivation of results for this study.

We prepared draft and revised residential and commercial postcards, and draft and revised surveys for review. We also reviewed the survey responses after about a dozen surveys to make sure key data were being reported in ways that would be useful for the analysis.

The photographs used to help respondents identify the key thermostat types are reproduced here; the thermostat survey questions are included in Appendix C at the end of the report.

Figure 3.1 Major Thermostat Types Provided in Photo Form within Web Questionnaire



4. Analyzing the Data: Bias Reduction and Estimations

4.1 The Validation Survey

Two validation efforts were undertaken. We conducted on-site validation survey of 30 respondents in the San Francisco Bay Area. In addition, late in the survey we selected 44 random respondents and sent them disposable cameras, incentive gift certificates to encourage return of the cameras, and a pre-paid postage return envelope. A letter included with the camera asked the respondents to photograph each thermostat in their dwelling or business. Preliminary results from this second validation effort were available for this report.

Validation Efforts: The validation efforts were undertaken to provide indications of the accuracy of self-reported data to support this study.

- **On-Site Validation**: A total of 30 site visits were conducted to inspect the accuracy of survey / self-reported thermostat counts and types. Site visits were conducted at 5 commercial businesses, 4 apartment units, and 21 single family residents across 8 counties in the State, covering a total of 96 thermostats. The inspections were conducted in Alameda, Contra Costa, Marin, Monterey, San Francisco, San Mateo, Santa Clara, and Sonoma Counties. The key results of the validation work are presented in Table 1.6 in Chapter 1. The inspections found three respondents (10%) mis-reported the number of thermostats, under-representing the number of thermostats in the market by 15% (one resident missed one thermostat, two larger commercial respondents missed more). Of the thermostats reported, four residents mixed up the types (three reported actual digitals as round or square types, and one reported a round as a digital) and no commercial respondents were incorrect in types reported (5% total error). Of a total of 14 thermostats missed in the count, half were new types not reported by the respondent (one square, one snap, three rounds, and two other). All but one of these was in one larger commercial establishment with an inaccurate count. While 30 site visits and 96 thermostats inspected is not a large sample, the number provides indicative data useful for helping providing bounds for the results of the analysis.[18]

- **Camera Validation**: In a second validation effort, we mailed disposable cameras to a sample of 44 businesses and households selected randomly from our respondents across the state. The sample was asked to take photographs of each thermostat in their home and return the camera in the pre-paid envelope, which would validate both count and types.[19] This method does not allow us to validate the percent that contain mercury,

[18] A random validation survey of 30 on-sites with 95 thermostats would provide +/-10% at 95% confidence on the thermostat data. Our validation survey was geographically clustered, so these are indicative percentages only. The randomly-scattered responses from the camera validation improve these properties. Cameras were sent to randomly-selected respondent locations in Los Angeles, Culver City, Beverly Hills, Yorba Linda, San Diego, Santa Maria, Stockton, Laguna Niguel, Oxnard, Jamul, Madera, Irvine, Redding, and many others.

[19] We provided a gift certificate to encourage return of the cameras.

except for the knowledge that digital thermostats do not contain mercury.[20] The responses have only just started to arrive; we have 12 replies in the first two days of responses that have been incorporated into this report. The results showed that of 9 residential respondents, accounting for a "reported" 11 thermostats, we had one error; there were actually 12 thermostats in place. On the commercial side, the 3 businesses were supposed to have a total of 14 thermostats, but there were 15 in total in the photographs. There were no errors in the reported thermostat "types". These results are also included in Table 1.6.

The combination of these two validation efforts finds that self-reports were correct in the majority of cases. There were five errors in "count" from the 42 validated sites (12% had errors); the errors in number were 4% from the residential side, and 15% from the commercial side. Using these figures, we find a total estimated weighted correction factor (given the total thermostats reported from the residential vs. commercial sectors) of about 13.5% undercounting of thermostats using self-reported figures. A total of 3.4% of the inspected thermostats were reported as the wrong type (all errors in the residential sector).

4.2 Responses and Patterns

Thanks to two rounds of postcards notifying of the survey, revisions to the second round to broaden interest in the survey (from just "thermostats" to "recycling and hard to recycle items", and pro-active calls by SERA staff to large businesses, we achieved our goal responses (270-380). About 85% responded to key questions related to the number and types of thermostats and similar data. Thus, our effective response rates were a bit lower, but still strong (see Table 4.1)

Table 4.1: Number of Respondents to the Thermostat Survey and Associated Confidence Levels

	Commercial	Residential	Total
Number of businesses and households in California (census 2006, 2008 estimates)	723,900[21]	13.4 million	14.1 million
Number of survey responses and associated confidence levels	267 +/-6% at 95% confid. +/-5% at 90% confid.	595 +.-3.3% at 95% and 90% confidence	862 +/-3.3% at 95% confid. +/-2.8% at 90% confid.
Number of responses responding to key thermostat questions, and associated confidence levels	195 +/- 7% at 95% confid. +/-5.9% at 90% confid.	549 +/-3.5% at both 90% and 95% confidence	744 +/-3.6% at 95% confid. +/-3% at 90% confid.

[20] Note that if "type" is enough, this validation method is quite fast and much less expensive than field-work / on-site visits, and would suit validation studies applied to large, easily distinguished or unique equipment (hot water heaters, solar installations, and many other types.).

[21] These are 723,900 businesses with employees from "US Census Bureau Statistics of US Businesses 2006: All Industries, CA". There are apparently a high number of non-employee businesses in the State. Census bureau "Quick Facts" shows "all firms" to be 2.9 million in California in 2002, and private non-farm firms as 892,000 ("establishments" in US All Industries is 878,128). We sampled from businesses with 1 or more employees. The splits used in this table are from the sampling frame provided by InfoUSA, our sample population. Splits from census are within a few percentage points of these figures.

4.3 Bias Reduction Analysis

Bias Reduction: Before we conducted any analyses, we reviewed the data for evidence of bias. There are two types of bias, each addressed below.

- **Response bias, unreturned surveys:** Systematic non-random patterns in returns or responses to surveys are a source of bias. For example, our sampling plan may have been designed to achieve 20% of our responses from small buildings, but we find we are only getting 10% from them, or patterns of data disproportionately for newer vs. older buildings (compared to the purchased sample or to data from national or regional studies). To check for basic patterns of non-representative responses, we examined two main variables: geographic patterns (we examined county), and responses by housing type and business size. The business size factor was especially important because we used a stratified random, not purely random sample for the business sector. In the commercial case, we sent out the surveys in a non-representative pattern (we oversampled large buildings so we could have greater accuracy for the businesses responsible for the bulk of thermostats in the State). Therefore, corrections (using "weights") for business size (reflected in employment category) were anticipated (for example, see Table 4.2, which shows 6% of responses from employment category 250+ and the census population is only 1%). The commercial and residential responses were assigned "weights" based on business size and housing unit type to provide better representation of the State's residential and commercial sectors.[22] We found that there were patterns in both the commercial and residential survey (Table 4.5, single vs. multi-family responses), and we applied weights that compensated for these patterns.[23] Graphs illustrating deviations by County for the residential and commercial sector are provided in Appendix A.

Table 4.2: Table of Completions and Ratios for Commercial Sector Respondents

	Responses	Response Percent	Census Count, CA	Census Percent	Ratio (related to weight)	Pop/SurveyN/1000
Commercial Businesses, all	267 (*)		891,987			3.5
Employees 1-4	45	17%	491,641	55%	3.2	10.9
Employees 5-9	17	7%	161,647	18%	2.8	9.5
Employees 10-19	38	15%	111,298	12%	0.8	2.9
Employees 20-49	46	18%	79,682	9%	0.5	1.7
Employees 50-99	15	6%	27,268	3%	0.5	1.8
Employees 100-249	11	4%	14,836	2%	0.4	1.3
Employees 250+	15	6%	5,615	1%	0.1	0.4

(*)258 answered question on employees

[22] To illustrate the correction method in a simplified way, if we got perfect responses from all categories, but twice as many from the elderly, their responses might be weighted as ½ each and then used in the database for computing less biased means, etc.
[23] Computed weights also varied by question based on responses to that question.

Table 4.3: Table of Completions and Ratios for Residential Sector Respondents

	Responses	Response Percent	Census, California	Census Percent	Ratio incl MF	Pop/Survey N/1000
Households, all	594		12,183,304[24]			20.5
Single family home, detached	455	77%	6,883,493	56%	0.74	15.1
Single family, attached / town home	55	9%	931,873	8%	0.83	16.9
Apartment 2-4	25	4%	1,024,803	8%	2.00	41.0
Apartment 5 or more	47	8%	2,804,712	23%	2.91	59.7
Manufactured home / mobile home	12	2%	538,423	4%	2.19	44.9

Not all identified home type; omitted minor census categories for residential

- **Patterns in Missing data from within surveys**: Another source of error results from missing data within a survey. For example, younger households may not know when the home was remodeled for a thermostat replacement, and a higher percent leave this answer blank. If this is systematic, it can lead to problems estimating models. Correction methods can be applied to address this issue, and are especially reliable in cases where there are responses from others that are "similar" or where explanatory variables can be used to fill in these missing data.[25] Our most critical data was the number of thermostats in the home or business. The number of non-responses was illustrated in Table 4.1. The main pattern we identified was that very large facilities (specifically an airport, a university campus), stated the number of thermostats in responses like "we have thousands". We had limited other "similar" facilities to use to estimate the total number of thermostats in these facilities, and we used a low end value for these facilities. We addressed the general issue of non-response to the key questions using weighting, rather than other (imputation-type) methods. The potential undercounting of thermostats in these large facilities may be an issue in general; however, the flow or disposal of mercury thermostats from these types of facilities is likely to be addressed in a responsible way. In addition, future studies may find it productive to conduct site visits of a small sample of these types of facilities, as it may not be practical to expect these facility managers to 1) know the count of thermostats, or 2) have the time available to conduct such a count.

4.4 Analysis of the Number of Thermostats

We conducted two key types of analysis: 1) estimating the total and average number of thermostats in businesses and households across California, and 2) examining the lifetimes of thermostats to identify the annual "flow" of the inventory of thermostats in the State that may be available for recycling (and hopefully avoided disposal).

Estimating the "Count" of Thermostats in place: We used the survey responses on 'number of wall thermostats in the place in your space' from the survey to estimate the count of

[24] The latest total of 13.4 million households was used to compute the total thermostats. This table was prepared using the previous household count, but the ratios between single and multifamily households, for weighting purposes, are the only difference and are relatively small.

[25] We have often used "hot deck" (see article by Ong, Holt, Barnes, and Skumatz in *"The Energy Journal"*, 1989) imputation methods to "impute" or put in replacement data – but drawing from our sample in doing so. To implement the "hot deck" method, one needs responses from sets of "similar" households (same age group, region, house type, etc.) and their responses are used to assign or fill in the response from a randomly-selected "similar" household. It is similar to "predicting" the response and filling that value in, but it has better statistical properties. This was not applied to this thermostat study.

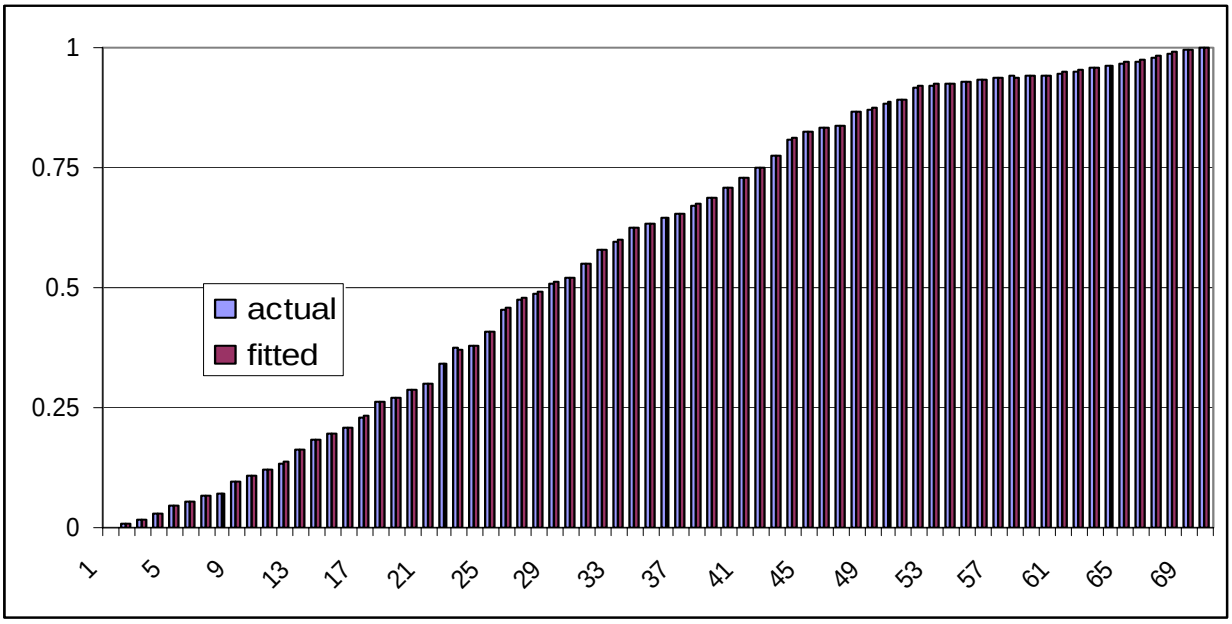
thermostats from survey responses, using weighted data to represent the population mean. The results of this analysis are included in Table 1.1.

4.5 Lifetimes / Annual Flow of Thermostats into the Market

Predict lifetime and annual "flow" of thermostats out of buildings: We used two methods to derive this estimate.[26] We graphed the actual lifetimes of thermostats, along with the results of a fitted model. These data are presented in Figure 4.1. The horizontal axis represents "years in place", and the vertical axis represents cumulative percent of the thermostats that age or younger. Note that this estimate demonstrates that about 50% of thermostats are still in place after 27.5 years. "Measure lifetime" literature in the energy efficiency field defines this "median value" as an "expected useful lifetime" or EUL. However, note that, within our sample, all the thermostats are not removed until about 70 years in place (technically, 68.5 years in our sample). The graph shows a flattening after about 50 years, at which the removal rate slows. This slowing at advanced ages is common in measure lifetimes (as well as humans!).

Figure 4.1: Cumulative Distribution - Approximate Actual and Fitted Measure Lifetime Curve Using Censored and Uncensored Data (gamma distribution as best fit, survey data)[27]

Cumulative Percent *Graph approximates function, not as smooth*



Years Installed

[26] Note that the data used for this analysis is necessarily imperfect. It is based on recall of current occupants, some of whom have been in the location a long time, and some were newer. However, the credibility of the data is bolstered by two results. The estimated EUL is about 25 years, which is very close to the EUL estimated by the CPUC and the DEER database, which is used Statewide by energy efficiency program planners and evaluators. Second, the measures last as long as 70 years, which is credible, as it corresponds to the types of age distributions we see for heating systems in the field (which are associated with thermostats).

[27] Uneven-ness in the graph is due to the author graphing estimates for "whole years", requiring interpolations between other numbers when whole-year lifetimes are not available; in addition, the graph is complicated by the "clusters" of data on certain points (e.g. many observations recalled at 10 years; fewer at 9 and 11, etc.). If graphed by formula, the "fitted" version would be smoother.

We used statistical modeling to develop projections of the measure lifetimes, taking into account both the thermostats that were in place, but removed (and for which we have data on estimated installation and removal years); and those that are still in place (and representing a variety of ages in the field). The former are "uncensored failures", and the latter are "right-censored" values. The censored values have not yet failed, and the statistical model works with both sets of data to develop the best projection of the decay curve / hazard function,[28] median value (estimated or expected useful lifetime - EUL) and various quartile values (See Table 4.4).[29] The approach represents best practices methods for measure lifetime analysis[30] for energy efficiency equipment.

Although these types of models are commonly used to estimate expected useful lifetimes, the model provides much more information. The cumulative percentage values can be used to predict the proportion of thermostats in place that would be expected to flow out of buildings each year into the future. The method uses the lifetimes of measures that have already been removed and the age of those still in place to predict how long the remaining equipment will last, and the model gives us an annual flow of removals in percentage terms. Although energy efficiency work focuses on the median or EUL, the proportions of projected failures / removals per year are of particular interest for this study of mercury thermostat flows.

In general terms, we then multiplied the inventory or "count" of thermostat equipment still in place (identified from the averages, or inventory step of the analyses, Table 1.1) times the annual flow rates from this model to compute the actual number expected to be removed each year from the residential vs. the commercial sectors (Figure 4.1).[31] The result is presented in Table 1.5.

These estimates can also be adjusted using the confidence intervals for the hazard function (Appendix B) and adjustments based on the validation survey, including adjustments to provide ranges in the "count" and types (and associated mercury-containing percent). The results and implications are included in the Executive Summary, Chapter 1 of this report.

Table 4.4: Quartile and Other Values for Fitted Thermostat "Flow" Model
(note confidence intervals are provided in the Table in Appendix B)

	10%	25%	50% (EUL)	75%	90%
Years in Place, overall	10	17.5	27.5	41.5	51.5

[28] The "decay" or "hazard" function approach comes from the health field, explaining deaths and illnesses, which we have applied to functional "deaths" of equipment.

[29] We tested other models, including residential vs. commercial, and omitting digital models. The quartile points varied by no more than 10% or 15%. Generally, the distribution for the residential sector extended longer (to 68.5 years) than the commercial sector (which was truncated at 49.5 years, likely because of recall issues, more than actual field differences). The median lifetime estimates varied by only 10-15% overall value presented in the Appendix. Thus, we opted for the "overall" model, preserving maximum data. Experimental analysis of differences for digital vs. non-digital models differences in the same range. The gamma distribution also had the best "fit" statistics (log likelihood and chi-square) of the five alternative distributions tested.

[30] Similar to the California Public Utilities Commission (CPUC) "Protocols" for estimating Effective Useful Lifetimes (EULs). For details on this approach, see Skumatz, "Best Practices in Measure Retention and Lifetime Studies: Standards for Reliable Measure Retention Methodology Derived from Extensive Review", Proceedings of the IEPEC Evaluation Conference, 2005, Brooklyn NY., and numerous similar studies by Skumatz (and others).

[31] Using statistical models, we tested different decay functions (log, exponential, gamma, etc.) to identify the best "fit". The performance of the alternative statistical models can be compared on the basis of a number of statistical "fit" measures, specifically Log-likelihood and chi-square probabilities. We presented the model with the best fit (gamma distribution), and the figures for "fit" compared to actual values are presented in the appendix..

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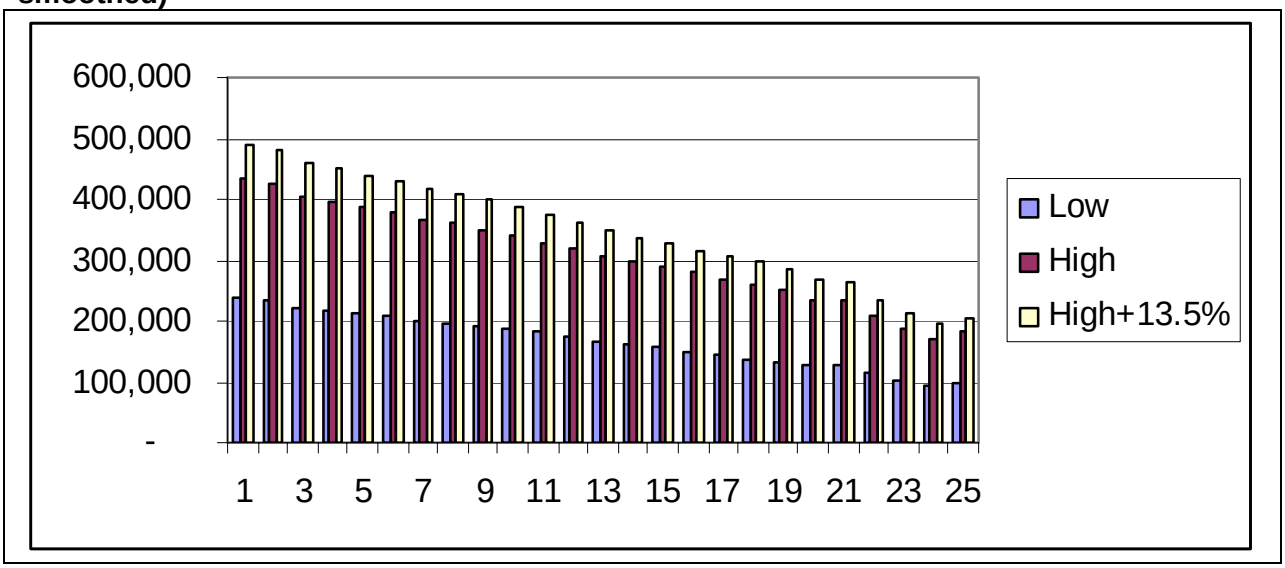
The actual computation of annual flows of mercury-containing thermostats from California homes and businesses, given the fact that all the thermostats in the marketplace were not installed at one time, is somewhat complicated. To develop the estimate, we used the cumulative distribution and expected lifetime model, along with survey data on the distribution of ages of installed thermostats. First, we deleted all digital thermostats (non-mercury) from the distribution, and second, we removed all thermostats with ages less than 3 (since mercury models were banned in 2006). Then we divided the total inventory of existing thermostats into quartiles, ranked by age of the thermostats currently installed.[32] We found 5% of the market had thermostats with ages of 6.5 years or less (5% incremental); 10% were 8.5 years or less (5% incremental); 25% were 13 years or less (an incremental 15%); 50% were 22 years or less (an incremental 25%); 75% were 34 years (an incremental 25%), and 90% had thermostats of 44 years or less, and we used that figure for the remaining 25% of the market.[33] Using the measure lifetime / cumulative distribution curve, we started at the years of life already expended, and adjusted the annual disposal streams for each cohort to conform with expecting 100% of the models to expire at about 70 years. Several of the cohorts were completely collected in the 25 years we show on the table (the cohort with 44 year old equipment or higher). We summed up the cohorts to develop the estimate of the total market that would flow out in a given year.[34] The estimated results are presented in Table 1.5 and are shown graphically below.[35]

Figure 4.2: Estimated Annual Flow of Mercury Thermostats into Market (first 25 Years, smoothed)



[32] We excluded digital thermostats because 1) they do not contain mercury, and 2) they are newer and would have skewed the quartiles toward "newer" equipment, and biased the flows downward. Mercury containing thermostats tend to be older equipment and may be expected to flow out at a faster rate than we would estimate if digital models were left in the computations.

[33] The number of cohorts was selected because statistical programs easily produce these quartile figures. More cohorts would not change the numbers substantially.

[34] based on lifetime expectations, not including adjustments for the poor near-term economy

[35] The excel approximation to the estimated model formula made slight waves in the data, which were smoothed somewhat with simple procedures.

Appendix A: Comparison of County Shares

Figure A.1. Deviations in Responses by County –Total Residential Housing Units

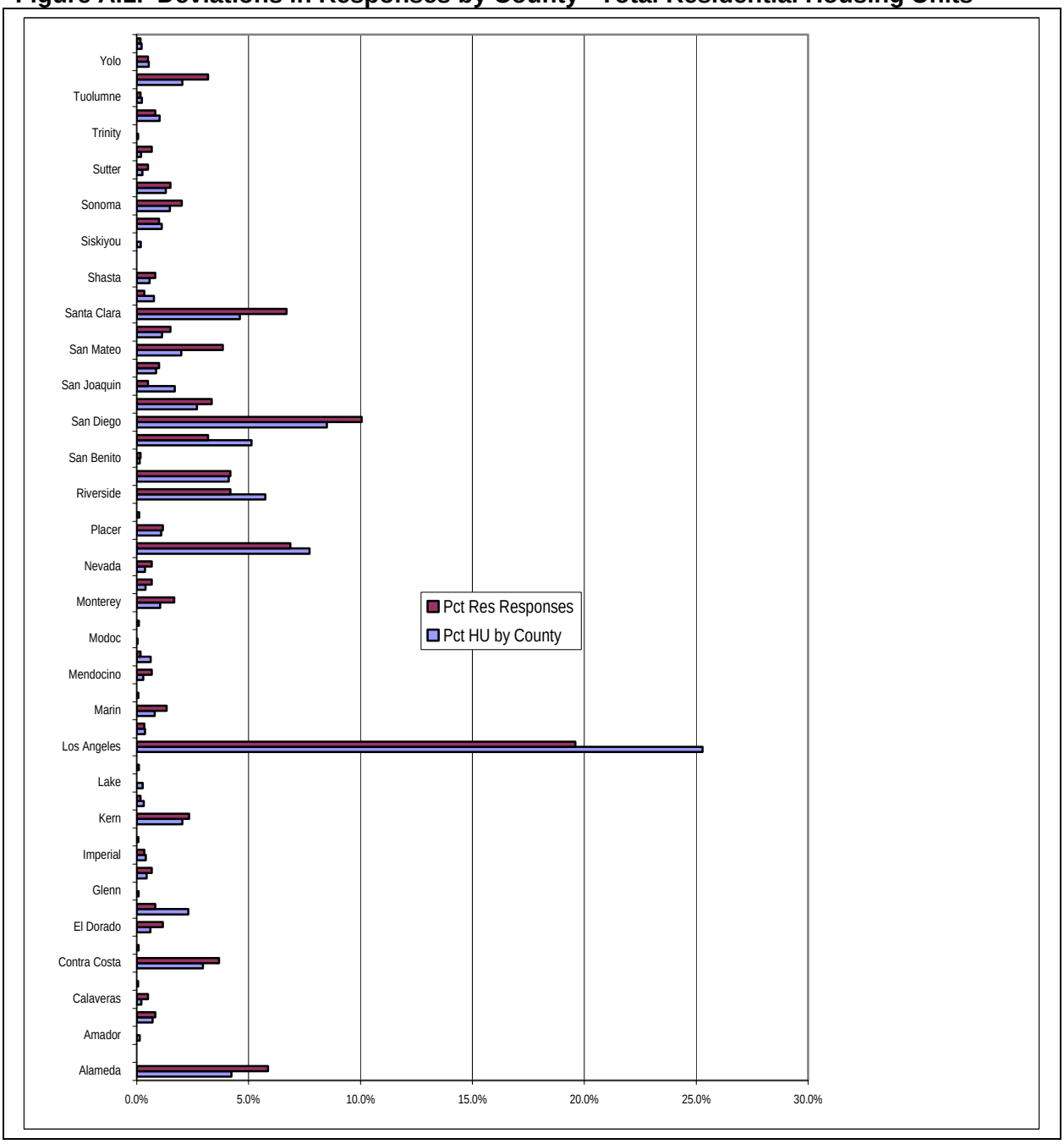


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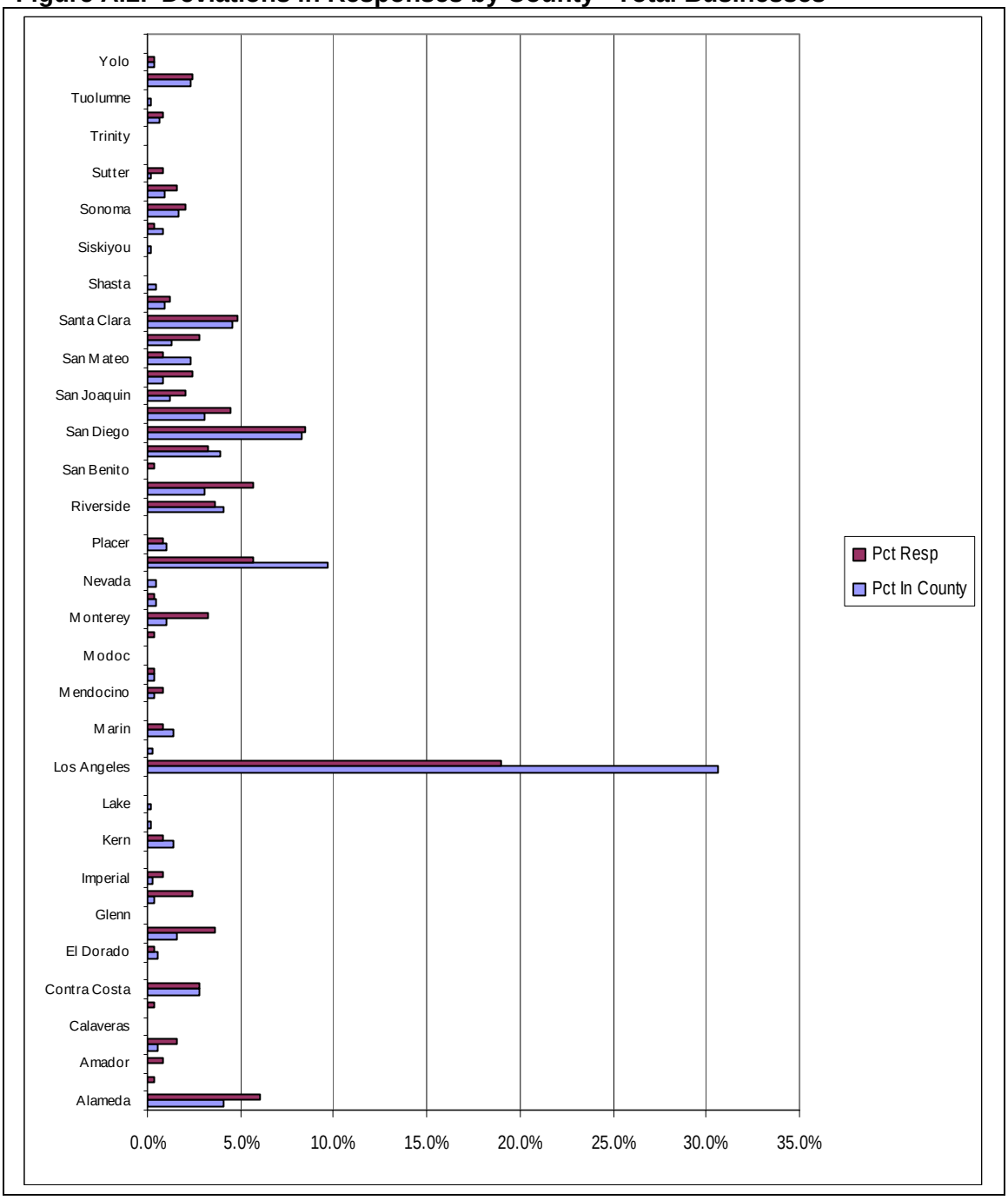
Figure A.2. Deviations in Responses by County –Total Businesses[36]



[36] Weighted averages presented in this report are based on business size (employment categories) and housing units in Single and multi-family dwellings. Using county response corrections as the weighting criteria were 1.2 for the residential mean (same as weighted; unweighted was 1.2), and 23.6 for the commercial mean (employment-weighted was 5.7, unweighted 23.9) because of the oversampling of large businesses. Combined weights were not considered because of the small cell counts that would be created in the business sector.

Appendix B: Values and Confidence Intervals for Fitted Measure Lifetime Curve

Cumulative actual probability and
Kaplan Meier Estimates and Confidence Intervals –
Thermostat Lifetimes based on censored and uncensored data
Cumulative Probability Estimates (approximately graphed in Figure 4.1)

Lifetime	Cumulative Probability	Simultaneous 95% Confidence Limits Lower	Upper	Kaplan-Meier Estimate	Kaplan-Meier Standard Error
2	0.0007	0.0014	0.0014	0.0014	0.0000
2	0.0021	0.0028	0.0028	0.0028	0.0000
2	0.0035	0.0042	0.0042	0.0042	0.0000
2	0.0049	0.0056	0.0056	0.0056	0.0000
2	0.0063	0.0070	0.0070	0.0070	0.0000
2	0.0077	0.0083	0.0084	0.0084	0.0000
2	0.0091	0.0097	0.0098	0.0098	0.0000
2	0.0105	0.0111	0.0112	0.0111	0.0000
2	0.0118	0.0125	0.0126	0.0125	0.0000
2	0.0132	0.0139	0.0140	0.0139	0.0000
2	0.0149	0.0159	0.0159	0.0159	0.0000
2	0.0169	0.0178	0.0179	0.0179	0.0000
4	0.0189	0.0200	0.0200	0.0200	0.0000
4	0.0207	0.0214	0.0215	0.0215	0.0000
4	0.0222	0.0229	0.0230	0.0230	0.0000
4	0.0237	0.0244	0.0245	0.0245	0.0000
4	0.0252	0.0259	0.0260	0.0260	0.0000
4	0.0267	0.0274	0.0275	0.0274	0.0000
4	0.0282	0.0289	0.0290	0.0289	0.0000
4	0.0297	0.0304	0.0305	0.0304	0.0000
4	0.0315	0.0325	0.0326	0.0325	0.0000
4	0.0333	0.0340	0.0341	0.0340	0.0000
4	0.0348	0.0355	0.0356	0.0355	0.0000
4	0.0363	0.0370	0.0371	0.0370	0.0000
4	0.0378	0.0385	0.0386	0.0385	0.0000
4	0.0393	0.0400	0.0400	0.0400	0.0000
5	0.0408	0.0416	0.0417	0.0416	0.0000
5	0.0428	0.0439	0.0440	0.0439	0.0000
5	0.0451	0.0462	0.0462	0.0462	0.0000
5	0.0474	0.0485	0.0485	0.0485	0.0000
5	0.0493	0.0501	0.0502	0.0501	0.0000
6	0.0509	0.0517	0.0518	0.0517	0.0000
6	0.0525	0.0533	0.0534	0.0534	0.0000
6	0.0535	0.0536	0.0537	0.0537	0.0000
6	0.0538	0.0539	0.0540	0.0540	0.0000
6	0.0541	0.0543	0.0543	0.0543	0.0000
6	0.0544	0.0546	0.0546	0.0546	0.0000
6	0.0554	0.0562	0.0563	0.0562	0.0000
6	0.0570	0.0578	0.0579	0.0578	0.0000
6.5	0.0587	0.0594	0.0595	0.0595	0.0000
6.5	0.0603	0.0610	0.0611	0.0611	0.0000

7	0.0619	0.0628	0.0629	0.0628	0.0000
7	0.0637	0.0645	0.0646	0.0645	0.0000
7	0.0654	0.0662	0.0663	0.0663	0.0000
7	0.0671	0.0679	0.0680	0.0680	0.0000
8	0.0689	0.0697	0.0698	0.0697	0.0000
8	0.0706	0.0714	0.0715	0.0714	0.0000
8	0.0717	0.0718	0.0719	0.0719	0.0000
8	0.0727	0.0735	0.0736	0.0736	0.0000
8	0.0738	0.0740	0.0740	0.0740	0.0000
8	0.0749	0.0757	0.0758	0.0757	0.0000
8.5	0.0759	0.0761	0.0762	0.0761	0.0000
8.5	0.0770	0.0778	0.0779	0.0779	0.0000
8.5	0.0787	0.0795	0.0796	0.0796	0.0000
8.5	0.0798	0.0800	0.0801	0.0800	0.0000
8.5	0.0802	0.0804	0.0805	0.0804	0.0000
8.5	0.0806	0.0808	0.0809	0.0808	0.0000
8.5	0.0817	0.0825	0.0826	0.0826	0.0001
8.5	0.0834	0.0843	0.0844	0.0843	0.0001
8.5	0.0852	0.0860	0.0861	0.0860	0.0001
8.5	0.0869	0.0877	0.0878	0.0878	0.0001
8.5	0.0886	0.0894	0.0895	0.0895	0.0001
8.5	0.0903	0.0912	0.0913	0.0912	0.0001
8.5	0.0921	0.0929	0.0930	0.0929	0.0001
8.5	0.0938	0.0946	0.0947	0.0947	0.0001
9	0.0956	0.0964	0.0965	0.0965	0.0001
9	0.0974	0.0982	0.0983	0.0983	0.0001
10	0.0992	0.1001	0.1002	0.1001	0.0001
10	0.1010	0.1019	0.1020	0.1019	0.0001
10	0.1021	0.1023	0.1024	0.1024	0.0001
10	0.1026	0.1027	0.1029	0.1028	0.0001
10	0.1030	0.1032	0.1033	0.1032	0.0001
10	0.1035	0.1036	0.1037	0.1037	0.0001
10	0.1039	0.1041	0.1042	0.1041	0.0001
10	0.1043	0.1045	0.1046	0.1046	0.0001
10	0.1048	0.1049	0.1051	0.1050	0.0001
10	0.1052	0.1054	0.1055	0.1054	0.0001
10	0.1057	0.1058	0.1059	0.1059	0.0001
10	0.1061	0.1063	0.1064	0.1063	0.0001
10	0.1065	0.1067	0.1068	0.1067	0.0001
10	0.1070	0.1071	0.1072	0.1072	0.0001
10	0.1074	0.1076	0.1077	0.1076	0.0001
10	0.1078	0.1080	0.1081	0.1081	0.0001
10	0.1083	0.1084	0.1086	0.1085	0.0001
10	0.1087	0.1089	0.1090	0.1089	0.0001
10	0.1092	0.1093	0.1094	0.1094	0.0001
10	0.1096	0.1098	0.1099	0.1098	0.0001
10	0.1100	0.1102	0.1103	0.1103	0.0001
10	0.1105	0.1106	0.1108	0.1107	0.0001
10	0.1109	0.1111	0.1112	0.1111	0.0001
10	0.1114	0.1115	0.1116	0.1116	0.0001
10	0.1118	0.1120	0.1121	0.1120	0.0001
10	0.1122	0.1124	0.1125	0.1124	0.0001
10	0.1127	0.1128	0.1129	0.1129	0.0001
10	0.1131	0.1133	0.1134	0.1133	0.0001
10	0.1135	0.1137	0.1138	0.1138	0.0001
10	0.1140	0.1141	0.1143	0.1142	0.0001

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10	0.1144	0.1146	0.1147	0.1146	0.0001
10	0.1149	0.1150	0.1151	0.1151	0.0001
10	0.1153	0.1155	0.1156	0.1155	0.0001
10.5	0.1164	0.1173	0.1174	0.1173	0.0001
10.5	0.1182	0.1191	0.1192	0.1191	0.0001
11.5	0.1201	0.1210	0.1211	0.1210	0.0001
11.5	0.1220	0.1229	0.1230	0.1229	0.0001
11.5	0.1239	0.1247	0.1249	0.1248	0.0001
11.5	0.1257	0.1266	0.1267	0.1267	0.0001
11.5	0.1276	0.1285	0.1286	0.1286	0.0001
11.5	0.1295	0.1304	0.1305	0.1305	0.0001
12	0.1314	0.1323	0.1324	0.1323	0.0001
12	0.1333	0.1342	0.1343	0.1342	0.0001
12	0.1352	0.1360	0.1362	0.1361	0.0001
12	0.1370	0.1379	0.1380	0.1380	0.0001
12	0.1389	0.1398	0.1399	0.1399	0.0001
12.5	0.1408	0.1417	0.1418	0.1418	0.0001
12.5	0.1427	0.1436	0.1437	0.1436	0.0001
12.5	0.1438	0.1439	0.1441	0.1440	0.0001
12.5	0.1442	0.1443	0.1444	0.1444	0.0001
12.5	0.1453	0.1462	0.1463	0.1462	0.0001
12.5	0.1472	0.1481	0.1482	0.1481	0.0001
12.5	0.1491	0.1499	0.1501	0.1500	0.0001
12.5	0.1510	0.1518	0.1520	0.1519	0.0001
12.5	0.1521	0.1523	0.1524	0.1523	0.0001
12.5	0.1533	0.1542	0.1543	0.1542	0.0001
12.5	0.1545	0.1546	0.1548	0.1547	0.0001
12.5	0.1549	0.1550	0.1551	0.1551	0.0001
12.5	0.1553	0.1554	0.1556	0.1555	0.0001
12.5	0.1564	0.1573	0.1575	0.1574	0.0001
12.5	0.1583	0.1592	0.1593	0.1593	0.0001
12.5	0.1595	0.1597	0.1598	0.1597	0.0001
12.5	0.1607	0.1615	0.1617	0.1616	0.0001
12.5	0.1618	0.1620	0.1621	0.1621	0.0001
12.5	0.1622	0.1624	0.1625	0.1624	0.0001
13.5	0.1634	0.1643	0.1645	0.1644	0.0001
13.5	0.1658	0.1671	0.1672	0.1672	0.0001
13.5	0.1681	0.1690	0.1692	0.1691	0.0001
13.5	0.1701	0.1710	0.1711	0.1711	0.0001
13.5	0.1721	0.1730	0.1731	0.1730	0.0001
13.5	0.1740	0.1749	0.1751	0.1750	0.0001
13.5	0.1760	0.1769	0.1770	0.1770	0.0001
13.5	0.1783	0.1796	0.1798	0.1797	0.0001
14	0.1807	0.1816	0.1818	0.1817	0.0001
14	0.1827	0.1836	0.1837	0.1836	0.0001
14.5	0.1842	0.1847	0.1849	0.1848	0.0001
14.5	0.1854	0.1859	0.1860	0.1860	0.0001
14.5	0.1865	0.1870	0.1872	0.1871	0.0001
14.5	0.1873	0.1875	0.1877	0.1876	0.0001
14.5	0.1878	0.1880	0.1881	0.1881	0.0001
14.5	0.1883	0.1885	0.1886	0.1885	0.0001
14.5	0.1888	0.1889	0.1891	0.1890	0.0001
14.5	0.1892	0.1894	0.1896	0.1895	0.0001
14.5	0.1897	0.1899	0.1900	0.1900	0.0001
14.5	0.1900	0.1900	0.1901	0.1901	0.0001
14.5	0.1901	0.1901	0.1903	0.1902	0.0001

14.5	0.1908	0.1913	0.1914	0.1913	0.0001
14.5	0.1914	0.1914	0.1915	0.1915	0.0001
14.5	0.1917	0.1919	0.1920	0.1919	0.0001
14.5	0.1922	0.1923	0.1925	0.1924	0.0001
14.5	0.1926	0.1928	0.1930	0.1929	0.0001
14.5	0.1939	0.1948	0.1949	0.1948	0.0001
14.5	0.1958	0.1967	0.1969	0.1968	0.0001
15.5	0.1970	0.1970	0.1972	0.1971	0.0001
15.5	0.1985	0.1998	0.1999	0.1999	0.0001
15.5	0.2009	0.2018	0.2019	0.2018	0.0001
15.5	0.2028	0.2037	0.2039	0.2038	0.0001
15.5	0.2052	0.2065	0.2066	0.2066	0.0001
15.5	0.2067	0.2068	0.2069	0.2069	0.0001
16.5	0.2078	0.2087	0.2089	0.2088	0.0001
16.5	0.2098	0.2107	0.2109	0.2108	0.0001
16.5	0.2118	0.2127	0.2128	0.2127	0.0001
16.5	0.2141	0.2154	0.2156	0.2155	0.0001
16.5	0.2169	0.2182	0.2184	0.2183	0.0001
17	0.2193	0.2202	0.2203	0.2202	0.0001
17	0.2212	0.2221	0.2223	0.2222	0.0001
17	0.2232	0.2241	0.2242	0.2242	0.0001
17	0.2251	0.2260	0.2262	0.2261	0.0001
17	0.2271	0.2280	0.2282	0.2281	0.0001
17	0.2291	0.2300	0.2301	0.2300	0.0001
17	0.2310	0.2319	0.2321	0.2320	0.0001
17	0.2330	0.2339	0.2340	0.2340	0.0001
17	0.2349	0.2358	0.2360	0.2359	0.0001
17	0.2369	0.2378	0.2380	0.2379	0.0001
17	0.2389	0.2398	0.2399	0.2398	0.0001
17	0.2408	0.2417	0.2419	0.2418	0.0001
17	0.2428	0.2437	0.2438	0.2438	0.0001
17	0.2447	0.2456	0.2458	0.2457	0.0001
17.5	0.2468	0.2477	0.2479	0.2478	0.0001
17.5	0.2488	0.2498	0.2499	0.2499	0.0001
17.5	0.2509	0.2518	0.2520	0.2519	0.0001
17.5	0.2529	0.2539	0.2541	0.2540	0.0001
17.5	0.2550	0.2560	0.2561	0.2560	0.0001
17.5	0.2571	0.2580	0.2582	0.2581	0.0001
17.5	0.2591	0.2601	0.2603	0.2602	0.0001
17.5	0.2612	0.2622	0.2623	0.2622	0.0001
18.5	0.2633	0.2642	0.2644	0.2643	0.0001
18.5	0.2653	0.2663	0.2665	0.2664	0.0001
18.5	0.2666	0.2668	0.2670	0.2669	0.0001
18.5	0.2671	0.2673	0.2675	0.2674	0.0001
18.5	0.2676	0.2678	0.2680	0.2679	0.0001
19.5	0.2700	0.2721	0.2723	0.2722	0.0001
19.5	0.2743	0.2764	0.2766	0.2765	0.0001
19.5	0.2766	0.2767	0.2769	0.2768	0.0001
19.5	0.2770	0.2770	0.2772	0.2771	0.0001
19.5	0.2773	0.2774	0.2775	0.2775	0.0001
19.5	0.2776	0.2777	0.2779	0.2778	0.0001
19.5	0.2779	0.2780	0.2782	0.2781	0.0001
19.5	0.2783	0.2783	0.2785	0.2784	0.0001
19.5	0.2786	0.2787	0.2788	0.2788	0.0001
19.5	0.2789	0.2790	0.2792	0.2791	0.0001
19.5	0.2792	0.2793	0.2795	0.2794	0.0001

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19.5	0.2796	0.2796	0.2798	0.2797	0.0001
19.5	0.2799	0.2800	0.2801	0.2801	0.0001
19.5	0.2802	0.2803	0.2805	0.2804	0.0001
19.5	0.2805	0.2806	0.2808	0.2807	0.0001
19.5	0.2809	0.2809	0.2811	0.2810	0.0001
19.5	0.2812	0.2813	0.2814	0.2813	0.0001
19.5	0.2815	0.2816	0.2818	0.2817	0.0001
19.5	0.2818	0.2819	0.2821	0.2820	0.0001
19.5	0.2822	0.2822	0.2824	0.2823	0.0001
19.5	0.2825	0.2826	0.2827	0.2826	0.0001
19.5	0.2828	0.2829	0.2831	0.2830	0.0001
19.5	0.2831	0.2832	0.2834	0.2833	0.0001
19.5	0.2835	0.2835	0.2837	0.2836	0.0001
19.5	0.2838	0.2839	0.2840	0.2839	0.0001
19.5	0.2841	0.2842	0.2844	0.2843	0.0001
19.5	0.2844	0.2845	0.2847	0.2846	0.0001
19.5	0.2848	0.2848	0.2850	0.2849	0.0001
19.5	0.2851	0.2852	0.2853	0.2852	0.0001
19.5	0.2854	0.2855	0.2857	0.2856	0.0001
19.5	0.2857	0.2858	0.2860	0.2859	0.0001
19.5	0.2861	0.2861	0.2863	0.2862	0.0001
19.5	0.2864	0.2865	0.2866	0.2865	0.0001
19.5	0.2867	0.2868	0.2870	0.2869	0.0001
20	0.2879	0.2888	0.2890	0.2889	0.0001
20	0.2900	0.2909	0.2911	0.2910	0.0001
20.5	0.2920	0.2930	0.2932	0.2931	0.0001
20.5	0.2941	0.2950	0.2952	0.2951	0.0001
21	0.2957	0.2963	0.2964	0.2964	0.0001
21	0.2970	0.2975	0.2977	0.2976	0.0001
21	0.2986	0.2995	0.2997	0.2996	0.0001
21	0.3002	0.3008	0.3009	0.3009	0.0001
21	0.3019	0.3028	0.3030	0.3029	0.0001
21	0.3035	0.3040	0.3042	0.3041	0.0001
21	0.3047	0.3053	0.3054	0.3054	0.0001
21.5	0.3064	0.3073	0.3075	0.3074	0.0001
21.5	0.3085	0.3094	0.3096	0.3095	0.0001
21.5	0.3097	0.3098	0.3100	0.3099	0.0001
21.5	0.3109	0.3119	0.3120	0.3119	0.0001
21.5	0.3130	0.3139	0.3141	0.3140	0.0001
21.5	0.3150	0.3160	0.3162	0.3161	0.0001
21.5	0.3163	0.3164	0.3166	0.3165	0.0001
21.5	0.3167	0.3168	0.3170	0.3169	0.0001
21.5	0.3171	0.3172	0.3174	0.3173	0.0001
21.5	0.3183	0.3192	0.3194	0.3193	0.0001
21.5	0.3195	0.3196	0.3198	0.3197	0.0001
21.5	0.3208	0.3217	0.3219	0.3218	0.0001
21.5	0.3228	0.3238	0.3240	0.3239	0.0001
21.5	0.3249	0.3258	0.3260	0.3259	0.0001
21.5	0.3261	0.3262	0.3264	0.3263	0.0001
21.5	0.3265	0.3266	0.3268	0.3267	0.0001
21.5	0.3278	0.3287	0.3289	0.3288	0.0001
21.5	0.3290	0.3291	0.3293	0.3292	0.0001
21.5	0.3294	0.3295	0.3297	0.3296	0.0001
21.5	0.3298	0.3299	0.3301	0.3300	0.0001
21.5	0.3302	0.3303	0.3305	0.3304	0.0001
21.5	0.3306	0.3307	0.3309	0.3308	0.0001

21.5	0.3310	0.3311	0.3313	0.3312	0.0001
21.5	0.3314	0.3315	0.3317	0.3316	0.0001
21.5	0.3318	0.3319	0.3321	0.3320	0.0001
22	0.3330	0.3339	0.3341	0.3340	0.0001
22	0.3351	0.3360	0.3362	0.3361	0.0001
22	0.3371	0.3381	0.3383	0.3382	0.0001
22	0.3392	0.3401	0.3403	0.3402	0.0001
22	0.3413	0.3422	0.3424	0.3423	0.0001
22	0.3433	0.3443	0.3445	0.3444	0.0001
22	0.3454	0.3463	0.3465	0.3464	0.0001
22	0.3475	0.3484	0.3486	0.3485	0.0001
22	0.3495	0.3505	0.3507	0.3506	0.0001
22.5	0.3516	0.3526	0.3528	0.3527	0.0001
22.5	0.3538	0.3548	0.3550	0.3549	0.0001
22.5	0.3571	0.3593	0.3595	0.3594	0.0001
22.5	0.3616	0.3638	0.3640	0.3639	0.0001
22.5	0.3661	0.3683	0.3685	0.3684	0.0001
22.5	0.3695	0.3704	0.3706	0.3705	0.0001
22.5	0.3716	0.3726	0.3728	0.3727	0.0001
23.5	0.3738	0.3748	0.3750	0.3749	0.0001
23.5	0.3759	0.3769	0.3771	0.3770	0.0001
24.5	0.3789	0.3806	0.3808	0.3807	0.0001
24.5	0.3826	0.3843	0.3845	0.3844	0.0001
24.5	0.3863	0.3880	0.3882	0.3881	0.0001
24.5	0.3892	0.3902	0.3904	0.3903	0.0001
24.5	0.3914	0.3923	0.3925	0.3924	0.0001
24.5	0.3935	0.3945	0.3947	0.3946	0.0001
24.5	0.3961	0.3975	0.3977	0.3976	0.0001
24.5	0.3978	0.3979	0.3981	0.3980	0.0001
24.5	0.3991	0.4000	0.4002	0.4001	0.0001
24.5	0.4012	0.4022	0.4024	0.4023	0.0001
24.5	0.4038	0.4052	0.4054	0.4053	0.0001
24.5	0.4055	0.4056	0.4058	0.4057	0.0001
24.5	0.4059	0.4059	0.4061	0.4060	0.0001
24.5	0.4071	0.4081	0.4083	0.4082	0.0001
25.5	0.4097	0.4111	0.4113	0.4112	0.0001
25.5	0.4123	0.4133	0.4135	0.4134	0.0001
25.5	0.4145	0.4155	0.4157	0.4156	0.0001
25.5	0.4166	0.4176	0.4178	0.4177	0.0001
25.5	0.4188	0.4198	0.4200	0.4199	0.0001
25.5	0.4209	0.4219	0.4221	0.4220	0.0001
25.5	0.4231	0.4241	0.4243	0.4242	0.0001
25.5	0.4257	0.4271	0.4273	0.4272	0.0001
25.5	0.4283	0.4293	0.4295	0.4294	0.0001
25.5	0.4305	0.4315	0.4317	0.4316	0.0001
25.5	0.4326	0.4336	0.4338	0.4337	0.0001
25.5	0.4348	0.4358	0.4360	0.4359	0.0001
25.5	0.4369	0.4379	0.4381	0.4380	0.0001
25.5	0.4391	0.4401	0.4403	0.4402	0.0001
25.5	0.4413	0.4422	0.4424	0.4423	0.0001
25.5	0.4434	0.4444	0.4446	0.4445	0.0001
25.5	0.4456	0.4466	0.4468	0.4467	0.0001
25.5	0.4473	0.4478	0.4480	0.4479	0.0001
25.5	0.4486	0.4491	0.4493	0.4492	0.0001
25.5	0.4503	0.4513	0.4515	0.4514	0.0001
25.5	0.4524	0.4534	0.4536	0.4535	0.0001

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25.5	0.4546	0.4556	0.4558	0.4557	0.0001
26.5	0.4568	0.4577	0.4579	0.4578	0.0001
26.5	0.4589	0.4599	0.4601	0.4600	0.0001
26.5	0.4611	0.4621	0.4623	0.4622	0.0001
26.5	0.4632	0.4642	0.4644	0.4643	0.0001
26.5	0.4654	0.4664	0.4666	0.4665	0.0001
26.5	0.4676	0.4685	0.4687	0.4686	0.0001
27	0.4697	0.4707	0.4709	0.4708	0.0001
27	0.4719	0.4729	0.4731	0.4730	0.0001
27	0.4740	0.4750	0.4752	0.4751	0.0001
27	0.4762	0.4772	0.4774	0.4773	0.0001
27	0.4784	0.4793	0.4795	0.4794	0.0001
27	0.4805	0.4815	0.4817	0.4816	0.0001
27	0.4827	0.4836	0.4839	0.4838	0.0001
27	0.4848	0.4858	0.4860	0.4859	0.0001
27.5	0.4871	0.4881	0.4883	0.4882	0.0001
27.5	0.4893	0.4904	0.4906	0.4905	0.0001
27.5	0.4929	0.4951	0.4954	0.4953	0.0001
27.5	0.4976	0.4999	0.5001	0.5000	0.0001
27.5	0.5012	0.5022	0.5024	0.5023	0.0001
27.5	0.5039	0.5054	0.5056	0.5055	0.0001
27.5	0.5072	0.5087	0.5089	0.5088	0.0001
27.5	0.5099	0.5109	0.5112	0.5111	0.0001
29.5	0.5122	0.5132	0.5134	0.5133	0.0001
29.5	0.5145	0.5155	0.5157	0.5156	0.0001
29.5	0.5172	0.5188	0.5190	0.5189	0.0001
29.5	0.5205	0.5220	0.5222	0.5221	0.0001
29.5	0.5232	0.5243	0.5245	0.5244	0.0001
29.5	0.5255	0.5266	0.5268	0.5267	0.0001
29.5	0.5273	0.5279	0.5281	0.5280	0.0001
31	0.5291	0.5302	0.5304	0.5303	0.0001
31	0.5314	0.5325	0.5327	0.5326	0.0001
31	0.5337	0.5348	0.5350	0.5349	0.0001
31	0.5360	0.5370	0.5373	0.5372	0.0001
31	0.5383	0.5393	0.5395	0.5394	0.0001
31	0.5406	0.5416	0.5418	0.5417	0.0001
31.5	0.5429	0.5439	0.5441	0.5440	0.0001
31.5	0.5452	0.5462	0.5464	0.5463	0.0001
31.5	0.5474	0.5485	0.5487	0.5486	0.0001
31.5	0.5497	0.5508	0.5510	0.5509	0.0001
31.5	0.5520	0.5531	0.5533	0.5532	0.0001
31.5	0.5543	0.5553	0.5556	0.5554	0.0001
31.5	0.5574	0.5593	0.5595	0.5594	0.0001
31.5	0.5613	0.5632	0.5634	0.5633	0.0001
31.5	0.5652	0.5671	0.5673	0.5672	0.0001
31.5	0.5675	0.5677	0.5679	0.5678	0.0001
31.5	0.5680	0.5682	0.5684	0.5683	0.0001
31.5	0.5686	0.5688	0.5690	0.5689	0.0001
31.5	0.5700	0.5710	0.5713	0.5711	0.0001
31.5	0.5723	0.5733	0.5735	0.5734	0.0001
31.5	0.5746	0.5756	0.5758	0.5757	0.0001
31.5	0.5769	0.5779	0.5781	0.5780	0.0001
31.5	0.5792	0.5802	0.5804	0.5803	0.0001
31.5	0.5814	0.5825	0.5827	0.5826	0.0001
31.5	0.5837	0.5848	0.5850	0.5849	0.0001
31.5	0.5860	0.5871	0.5873	0.5872	0.0001

31.5	0.5883	0.5893	0.5895	0.5894	0.0001
31.5	0.5906	0.5916	0.5918	0.5917	0.0001
32	0.5929	0.5939	0.5941	0.5940	0.0001
32	0.5952	0.5962	0.5964	0.5963	0.0001
33.5	0.5974	0.5985	0.5987	0.5986	0.0001
33.5	0.5997	0.6008	0.6010	0.6009	0.0001
33.5	0.6020	0.6031	0.6033	0.6032	0.0001
33.5	0.6043	0.6053	0.6056	0.6054	0.0001
33.5	0.6066	0.6076	0.6078	0.6077	0.0001
33.5	0.6089	0.6099	0.6101	0.6100	0.0001
33.5	0.6116	0.6131	0.6134	0.6133	0.0001
33.5	0.6149	0.6164	0.6166	0.6165	0.0001
33.5	0.6176	0.6187	0.6189	0.6188	0.0001
33.5	0.6199	0.6209	0.6212	0.6211	0.0001
33.5	0.6222	0.6232	0.6234	0.6233	0.0001
33.5	0.6245	0.6255	0.6257	0.6256	0.0001
35.5	0.6269	0.6281	0.6283	0.6282	0.0001
35.5	0.6294	0.6306	0.6308	0.6307	0.0001
35.5	0.6320	0.6332	0.6334	0.6333	0.0001
35.5	0.6345	0.6357	0.6359	0.6358	0.0001
35.5	0.6371	0.6383	0.6385	0.6384	0.0001
35.5	0.6396	0.6408	0.6410	0.6409	0.0001
35.5	0.6422	0.6434	0.6436	0.6435	0.0001
35.5	0.6447	0.6459	0.6461	0.6460	0.0001
37	0.6473	0.6485	0.6487	0.6486	0.0001
37	0.6498	0.6510	0.6512	0.6511	0.0001
37	0.6524	0.6536	0.6538	0.6537	0.0001
37	0.6549	0.6561	0.6563	0.6562	0.0001
37	0.6575	0.6587	0.6589	0.6588	0.0001
37	0.6600	0.6612	0.6614	0.6613	0.0001
37.5	0.6626	0.6638	0.6640	0.6639	0.0001
37.5	0.6651	0.6663	0.6665	0.6664	0.0001
37.5	0.6677	0.6689	0.6691	0.6690	0.0001
37.5	0.6702	0.6714	0.6716	0.6715	0.0001
37.5	0.6728	0.6740	0.6742	0.6741	0.0001
37.5	0.6753	0.6765	0.6767	0.6766	0.0001
39.5	0.6779	0.6791	0.6793	0.6792	0.0001
39.5	0.6804	0.6816	0.6818	0.6817	0.0001
39.5	0.6830	0.6841	0.6844	0.6843	0.0001
39.5	0.6855	0.6867	0.6869	0.6868	0.0001
41	0.6881	0.6892	0.6894	0.6893	0.0001
41	0.6906	0.6918	0.6920	0.6919	0.0001
41	0.6932	0.6943	0.6945	0.6944	0.0001
41	0.6957	0.6969	0.6971	0.6970	0.0001
41	0.6973	0.6975	0.6977	0.6976	0.0001
41	0.6979	0.6981	0.6983	0.6982	0.0001
41	0.6985	0.6987	0.6989	0.6988	0.0001
41	0.6991	0.6994	0.6996	0.6995	0.0001
41	0.6998	0.7000	0.7002	0.7001	0.0001
41	0.7004	0.7006	0.7008	0.7007	0.0001
41	0.7010	0.7012	0.7014	0.7013	0.0001
41.5	0.7026	0.7038	0.7040	0.7039	0.0001
41.5	0.7051	0.7063	0.7065	0.7064	0.0001
41.5	0.7082	0.7099	0.7101	0.7100	0.0001
41.5	0.7118	0.7135	0.7137	0.7136	0.0001
41.5	0.7154	0.7171	0.7173	0.7172	0.0001

41.5	0.7190	0.7207	0.7209	0.7208	0.0001
41.5	0.7221	0.7232	0.7234	0.7233	0.0001
41.5	0.7251	0.7268	0.7270	0.7269	0.0001
41.5	0.7282	0.7294	0.7296	0.7295	0.0001
41.5	0.7308	0.7319	0.7321	0.7320	0.0001
41.5	0.7333	0.7345	0.7347	0.7346	0.0001
41.5	0.7359	0.7370	0.7372	0.7371	0.0001
41.5	0.7398	0.7424	0.7426	0.7425	0.0001
41.5	0.7451	0.7477	0.7479	0.7478	0.0001
41.5	0.7490	0.7502	0.7504	0.7503	0.0001
41.5	0.7516	0.7528	0.7530	0.7529	0.0001
41.5	0.7555	0.7581	0.7583	0.7582	0.0001
41.5	0.7608	0.7634	0.7636	0.7635	0.0001
41.5	0.7662	0.7687	0.7689	0.7688	0.0001
41.5	0.7715	0.7740	0.7742	0.7741	0.0001
43.5	0.7768	0.7794	0.7795	0.7794	0.0001
43.5	0.7821	0.7847	0.7849	0.7848	0.0001
43.5	0.7860	0.7872	0.7874	0.7873	0.0001
43.5	0.7886	0.7898	0.7900	0.7899	0.0001
43.5	0.7911	0.7923	0.7925	0.7924	0.0001
43.5	0.7937	0.7949	0.7950	0.7950	0.0001
43.5	0.7962	0.7974	0.7976	0.7975	0.0001
43.5	0.7988	0.8000	0.8001	0.8001	0.0001
43.5	0.8013	0.8025	0.8027	0.8026	0.0001
43.5	0.8039	0.8051	0.8052	0.8052	0.0001
43.5	0.8064	0.8076	0.8078	0.8077	0.0001
43.5	0.8090	0.8102	0.8103	0.8103	0.0001
45.5	0.8117	0.8131	0.8132	0.8131	0.0001
45.5	0.8146	0.8159	0.8161	0.8160	0.0001
45.5	0.8175	0.8188	0.8190	0.8189	0.0001
45.5	0.8204	0.8217	0.8219	0.8218	0.0001
45.5	0.8232	0.8246	0.8248	0.8247	0.0001
45.5	0.8261	0.8275	0.8277	0.8276	0.0001
45.5	0.8290	0.8304	0.8306	0.8305	0.0001
45.5	0.8319	0.8333	0.8334	0.8334	0.0001
47.5	0.8348	0.8362	0.8363	0.8362	0.0001
47.5	0.8377	0.8390	0.8392	0.8391	0.0001
47.5	0.8406	0.8419	0.8421	0.8420	0.0001
47.5	0.8435	0.8448	0.8450	0.8449	0.0001
47.5	0.8464	0.8477	0.8479	0.8478	0.0001
47.5	0.8492	0.8506	0.8508	0.8507	0.0001
47.5	0.8521	0.8535	0.8537	0.8536	0.0001
47.5	0.8550	0.8564	0.8565	0.8565	0.0001
47.5	0.8579	0.8593	0.8594	0.8594	0.0001
47.5	0.8608	0.8622	0.8623	0.8622	0.0001
47.5	0.8637	0.8650	0.8652	0.8651	0.0001
47.5	0.8666	0.8679	0.8681	0.8680	0.0001
49.5	0.8681	0.8681	0.8683	0.8682	0.0001
49.5	0.8683	0.8683	0.8684	0.8684	0.0001
49.5	0.8698	0.8712	0.8713	0.8712	0.0001
49.5	0.8727	0.8741	0.8742	0.8741	0.0001
49.5	0.8756	0.8769	0.8771	0.8770	0.0001
49.5	0.8785	0.8798	0.8800	0.8799	0.0001
49.5	0.8814	0.8827	0.8829	0.8828	0.0001
49.5	0.8842	0.8856	0.8858	0.8857	0.0001
49.5	0.8871	0.8885	0.8886	0.8886	0.0001

49.5	0.8900	0.8914	0.8915	0.8915	0.0001
51.5	0.8929	0.8943	0.8944	0.8944	0.0001
51.5	0.8958	0.8972	0.8973	0.8972	0.0001
51.5	0.8987	0.9001	0.9002	0.9001	0.0001
51.5	0.9016	0.9029	0.9031	0.9030	0.0001
51.5	0.9045	0.9058	0.9060	0.9059	0.0001
51.5	0.9073	0.9087	0.9089	0.9088	0.0001
51.5	0.9102	0.9116	0.9117	0.9117	0.0001
51.5	0.9131	0.9145	0.9146	0.9146	0.0001
51.5	0.9160	0.9174	0.9175	0.9175	0.0001
51.5	0.9189	0.9203	0.9204	0.9203	0.0001
51.5	0.9218	0.9232	0.9233	0.9232	0.0001
51.5	0.9247	0.9261	0.9262	0.9261	0.0001
56	0.9280	0.9299	0.9300	0.9300	0.0001
56	0.9319	0.9337	0.9338	0.9338	0.0001
56	0.9357	0.9376	0.9377	0.9376	0.0001
60.5	0.9395	0.9414	0.9415	0.9414	0.0001
60.5	0.9434	0.9452	0.9453	0.9453	0.0001
62.5	0.9472	0.9491	0.9492	0.9491	0.0001
62.5	0.9510	0.9529	0.9530	0.9529	0.0001
66.5	0.9557	0.9583	0.9584	0.9584	0.0001
66.5	0.9611	0.9637	0.9638	0.9638	0.0000
66.5	0.9665	0.9691	0.9692	0.9692	0.0000
66.5	0.9719	0.9745	0.9746	0.9746	0.0000
68.5	0.9765	0.9784	0.9785	0.9784	0.0000
68.5	0.9803	0.9822	0.9823	0.9823	0.0000
68.5	0.9842	0.9860	0.9861	0.9861	0.0000
68.5	0.9880	0.9899	0.9899	0.9899	0.0000
68.5	0.9918	0.9937	0.9938	0.9937	0.0000
68.5	0.9957	0.9976	0.9976	0.9976	0.0000

Appendix C: Thermostat Questionnaire

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