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Estimated Annual Outflow of Mercury-Containing Thermostats in the State of Illinois

Prepared for:

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Organization of the Report

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1. Project Background and Executive Summary

Discussion of Illinois Law

The Illinois Mercury Thermostat Collection Act, enacted in 2010, established a mandatory collection and recycling regime aimed at significantly improving the number of mercury thermostats previously collected under a manufacturer take-back program. The law requires heating, ventilation and cooling (HVAC) contractors or service technicians to recycle mercury-switch thermostats that are taken out of service, beginning July 1, 2011, and requires thermostat manufacturers to pay for the transportation of the collected mercury-switch thermostats to an appropriate recycling facility. The law also establishes goals for the collection of mercury-switch thermostats in the first four years of the program, requires the Illinois Environmental Protection Agency (IEPA) to set the collection goals for 2015 to 2020, and authorizes IEPA to mandate improvements to the collection programs if the goals are not achieved. The mercury thermostat collection law sunsets on January 1, 2021.[1]

To set the performance goals for the program beginning in 2015, IEPA is required to consider, among other factors, any reports or studies on the number of out-of-service mercury thermostats that are available for collection in Illinois and other states. IEPA must set the collection goals by November 1, 2014.

Summary of the Project's Steps

Under a contract to the Natural Resources Defense Council (NRDC) and the Multi-State Mercury Products Campaign, Clean Water Fund, the research and consulting firm Skumatz Economic Research Associates (SERA) of Superior, Colorado, developed a statistically-valid estimate of the mercury-containing thermostats that annually become waste in Illinois.[2]

To develop the required estimates, SERA conducted the following project activities:

- Reviewed past work and the literature to develop and refine the technical approach for the project;
- Developed a web survey including the key questions needed to develop estimates to support the analysis;
- 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 (toll-free phone number also provided for those wishing to complete via phone);

[1] Additional information on the Illinois law can be found at http://www.epa.state.il.us/mercury/thermostat-recycling/.

[2] This report represents the analysis and conclusions of SERA, not of NRDC or the Clean Water Fund.

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- Mailed a second postcard and outreach via email to the commercial sector sample to improve the statistical properties and increase the response count;
- Analyzed the data gathered from the survey;
- Conducted an effort to validate and provide additional context for the survey responses to be used in the analysis, consisting of interviews with 30 HVAC (heating, ventilation, and air conditioning) contractors around the state to gather information on installation / removal practices and patterns, and feedback on mercury-containing thermostat prevalence in buildings in the state;
- Conducted an effort to validate and provide additional context for the survey responses to be used in the analysis, by reaching out to a sample of respondents to request counts and photos of the installed thermostats to allow verification of the accuracy and consistency of responses regarding reporting of thermostat counts and types;
- Helped guide an effort to validate and provide additional context for the survey responses to be used in the analysis, which consisted of on-site visits to 46 respondent premises to verify accuracy of the survey responses on thermostat type and to provide inspection-based information on the presence of mercury in specific thermostat types (round, square, etc.)
- Prepared this report providing the study results and methods.

This report relies on surveys and statistical techniques to derive a defensible estimate of total annual mercury thermostat removals in Illinois, which may be used to advise the establishment of State goals for mercury thermostat recycling performance. The study analyzed information from more than 760 surveys, and the estimates show about 7.7 million thermostats in place in Illinois (1.86 million with mercury). The number of mercury-containing thermostats flowing out of residential and commercial buildings in the state is approximately 102,000 annually over the next 6 years, and 65,000 annually over the following 5 years. On average, mercury-containing thermostats are older; therefore, although they comprise only about 24% of the total thermostats on Illinois walls, they represent nearly three-quarters of the thermostats that are expected to be removed in the first few years (and about one-third of the thermostats removed for the next 10 years). Only one in four thermostats on Illinois walls is mercury-containing, largely because, according to the surveys, digital thermostats (which do not contain mercury) represent more than two-thirds of thermostats on the wall in both residential and commercial buildings. According to inspections and interviews, only two kinds of thermostats are majority mercury-containing – the square (about 85% contain mercury) and round (more than 95% contain mercury). Together, these represent almost one fourth of thermostats on the walls, and virtually all of the mercury-containing thermostats in the State.

Figure 1.1 Summary Statistics of Thermostat Results for Illinois

Summary Results	Residential	Commercial	Total
Number of Households or Establishments (thousands)	5,297	312	5,610
Average Thermostats per Unit	1.15	5.16	1.38
Number of Thermostats in place (thousands)	6,116	1,611	7,727
Thermostat "Count" Correction Factor from Validations	100%	98%	100%
Revised Number of Thermostats in Place (Thousands)	6,116	1,579	7,696
Percent of In-Building Thermostats containing Mercury	24.2%	24.2%	24.2%
Estimated Number of Mercury-containing thermostats in place (Thousands)	1,481	382	1,864

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Figure 1.2: Estimated Five Year Averages of Outflows of Mercury-Containing Thermostats from Illinois

5-6 Year Periods	Mercury-containing thermostats (thousands)	Non-Mercury-containing thermostats (thousands)	Mercury Thermostats: Cumulative Percent flowed out	Non-mercury thermostats: Cumulative Percent flowed out
2014-2019	102	133	33%	14%
2020[3]-2024	65	161	50%	27%
2025-2029	56	152	65%	40%
2030-2034	43	133	77%	52%
2035-2039	36	110	86%	61%
2040-2044	38	99	97%	70%
2045-2049	12	88	100%	77%
2050-2054		65		83%
2055-2059		51		87%
2060-2064		39		91%
2065-2069		32		93%
2070-2074		41		97%
Total to 2074	1,864	5,655		

As Figure 1.2 indicates, if the Illinois program sunsets at the end of 2020 as the current law provides, the majority of mercury thermostats currently in place will not be collected by the program. The implications of the number of the mercury thermostats remaining, and associated outflow predictions, for the IEPA collection goals rulemaking, are discussed further below. In general, however, if a goal of at least 50% recovery by the end of 2020 sunset date is desired, then:

- Natural outflows would need to be increased by 62% or double (through incentives or policies),
- Recycling recovery rates of the available mercury thermostats would need to reach 85% (if flows are enhanced 62%), or recovery rates of at least 67% would be needed under flows double those expected naturally, and
- Programs would need to be designed to identify and recover an average of 134,000 mercury thermostats for each of years 2014-2020.

Background and Context

A number of states are passing mandatory mercury thermostat collection laws and associated collection goals. However, little quantitative information is available on the number of mercury-containing thermostats currently in buildings or the expected flows of these devices out of buildings. As a consequence, some states have established goals using rules of thumb or simplistic assumptions. This study used primary field data to develop estimates of – and confidence intervals around – the values of interest.

[3] The last year before the Illinois Mercury Thermostat Collection Act sunsets.

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Background on the Literature

Three existing studies were reviewed in the preparation of this research study. A more detailed review of the literature is provided in Appendix A.

- King County WA sent professional staff to a sample of businesses and counted thermostats; they found the number of thermostats in the non-residential sector varied with year built, remodel year, square feet, and dominant building use. This project tested the performance of on-site inspection as a means of conducting studies of this type.

- The next work was conducted by SERA on California residential and commercial thermostats – using surveys of businesses and households on existing and removed thermostats by type, along with statistical models, to develop estimates of inventories of mercury thermostats in place, measure lifetimes, and projected flows of removals of mercury vs. non-mercury models. The study was commissioned (by the Thermostat Recycling Coalition) to meet State requirements that the industry propose a methodological approach to estimating thermostat flows.

- In 2010, the Product Stewardship Institute tested two approaches. It used Frost and Sullivan national sales data-based estimates of thermostat turnover, and scaled the figures (using population) to develop estimates of the number of thermostats in the replacement market (thus, representing one estimate of the potential of thermostats flowing out). This did not answer the question of how many contained mercury. They tested two approaches for contractor surveys to gather information on the percent of wall thermostats that contained mercury, but found that response rates from contractors, even with backing from industry associations, were problematic, and the pilot project was not able to find an inexpensive approach to address that part of the question.

Summary of the Approach Used in This Study

For the Illinois estimation work, we conducted a multi-step analysis with core similarities to the California DTSC study and incorporating some revisions reflecting peer review of the California study. The analysis consisted of the following steps:

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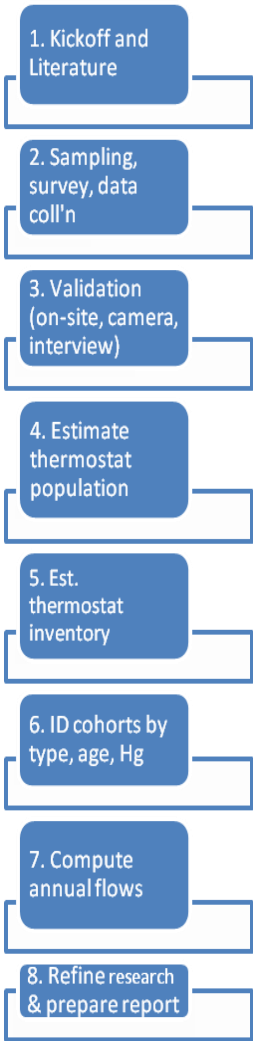
Figure 1.1: Summary of Research Steps



- **Data collection**: Send surveys to an appropriate random sample of homes, and stratified random sample of businesses in the state to ask about the number and types of thermostats in place, and information on ages and removals, and other useful background information.[4]

- **Validation and research efforts**: Conduct in-field validation and research work, including three efforts. 1) Because it was not considered practical to ask households or businesses to open and inspect their thermostats for mercury, we sent trained staff (from a non-profit firm) to a random number of returned survey locations to validate the reported count and type, and to open and inspect whether the thermostats in place contain mercury, and potentially age/ other information (this effort was conducted by NRDC, with SERA providing the sample to be surveyed); 2) by phone and email, request photos of all thermostats in place in a random set of survey respondent locations to verify the "count" and types of thermostats compared to survey responses; and 3) conduct interviews with a sample of Illinois HVAC contractors to better understand thermostat installation and removal practices (current and historical), and estimates of the percent of thermostats eligible for removal that contain mercury or not. This validation work provided additional sources of information for the inputs used in the computations.

- **Estimate Measure Lifetime or Decay Curve**: From survey data on ages and removals of thermostats in residential and commercial buildings, use appropriate statistical techniques (hazard functions) that are commonly used to estimate lifetimes of energy-using appliances and equipment to estimate the expected measure lifetimes (expressed as median expected or effective useful life / EUL) of thermostats and the associated "decay" or removal distribution.

- **Compute Existing Thermostat Population on Walls**: Use survey data to estimate the average number of thermostats in place in residences[5], and multiply by the number of residences to compute the total number of residential thermostats in homes. Use appropriate sample

[4] Note that the survey was presented or distributed to the sample as a 'recycling and hard-to-recycle' survey, and included simple questions about standard household or business recycling first. The survey was presented to respondents in this way to achieve two aims: 1) to try to get higher responses than might be achieved if it was presented as a thermostat survey (thermostat questions may not be perceived as interesting or as easily answered to most respondents as questions about traditional recyclables); 2) to try to ensure that we received responses from households (or businesses) without thermostats, who might elect not to engage in a survey presented as concentrated on thermostats.

[5] Including buildings with zero thermostats.

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weights to compute the total number of thermostats in commercial buildings. This is the total number of thermostats that are, essentially, "available" to be removed / recycled / disposed over time.[6]

- **Identify Cohorts by Thermostat Type**: For each type of thermostat in place in the state, compute the total number of each type of thermostat in place, and average age and age distribution of the remaining cohort of that thermostat type that is currently in place on walls across the State.

- **Estimate Annual Outflows of Mercury-Containing Thermostats**: Compute the total number of mercury-containing thermostats on walls by multiplying the total thermostats by type, times the percent of each type that contain mercury. Use the lifetime / decay curve to estimate the distribution of remaining lifetimes by thermostat type, accounting for their age cohorts, and compute the flow of mercury-containing thermostats available to be recycled annually into the future.

Each step of the research provides a key part of the calculation:

- A: Inventory or "count" of thermostats in place and available for removal and/or recycling: from the web survey (weighted appropriately), with corrections as needed (in count and type) from the on-site and camera validation work.
- B: Percent of the thermostat inventory in place in buildings that contain mercury: from the in-field validation work by NRDC, augmented with input from the contractors.
- C: Lifetime and decay function of thermostats in the field: from statistical analysis of survey responses on operating years of thermostats still operating and those that have been removed.
- D: Age / distribution, and resulting outflow of the thermostat inventory in place in the field: from the web survey responses stating the best estimate of the year that existing cohorts of mercury-containing thermostats were installed, applied to the life decay function, resulting in estimates of mercury-containing thermostats "aging out" of buildings in the State.

The logic of the estimation work is summarized as follows:

A times B (resulting in the number of mercury-containing thermostats currently in buildings) have a distribution of ages (D), which can be expected to come out of service according to a decay function (expected useful life distribution, C). This is our flow of thermostats available for recycling.

One additional complexity was introduced in order to provide more refined estimates; however, the computation methods remain essentially the same. Rather than asking about "wall thermostats" in general, the survey and validation work asked about specific subgroups of thermostats. They are illustrated below, and comprise five key types:

[6] The computation of the percent that are mercury takes place in a later step in this discussion.

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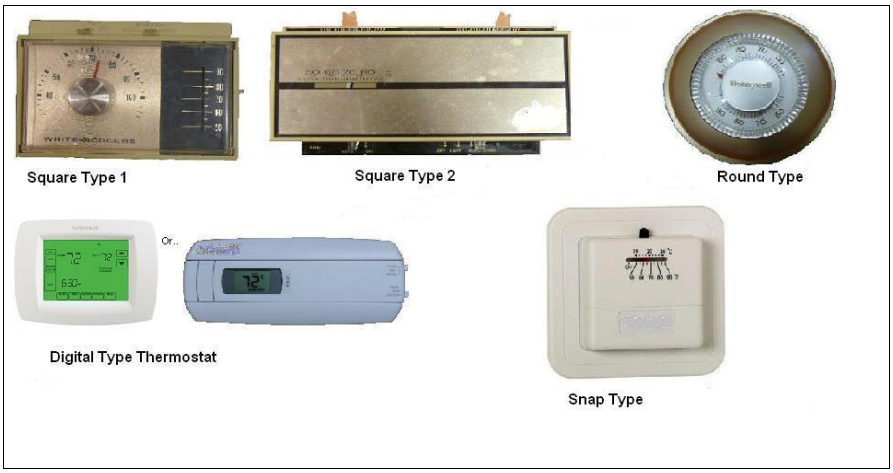
- Digital
- Round
- Square (not digital)
- Lever
- Snap
- Other



This allowed us to incorporate known information about some types of thermostats, recognizing that the thermostats each represented a key technology at a point in time, and avoiding the answer "it depends" when speaking with contractors and others about how many thermostats had mercury. It also replicated industry typology used in the SERA / DTSC / TRC study, allowing leveraging of information.

The results combine to provide an estimate of annual mercury-containing thermostat removals, which is key information needed for setting goals for recycling and informing program development in the State.

We developed this approach after reviewing alternatives available in the literature and peer review comments on the approaches, and conducting an assessment of the strengths and weaknesses of the alternatives (relative to reasonable budget constraints).[7] This is a strong approach, with good performance demonstrated in the confidence intervals and "fit" statistics for the model, as outlined below. Evaluation is designed to provide information to guide better decision-making, and the estimates included are defensible and support program design and goal-setting applications; the sample sizes were strong.

[7] On-site work can cost 7-50 times the cost of surveys; it would be prohibitively expensive to acquire as large a sample as we obtained (and as many failures / change-outs as were noted) using purely on-site methods.

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2. Conducting Steps A & B: Deriving an Estimated Inventory / "Count" of Mercury-Containing Thermostats in Illinois Buildings

Population and Sample: The survey was based on a purchased sample.[8] To represent the residential sector, a simple random sample of residential and multi-family addresses across the State was purchased. Our implicit assumption was that homes were fairly homogeneous, and there was no particular reason, *a priori*, to assume that there were systematic differences in the lifetimes of thermostats in homes[9], so a random sample design would suffice.

To represent the commercial sector, a stratified random sample design was selected. To recognize the complexity and potential differentiation within the commercial sector, we stratified on classes of number of employees at the establishment. There are many small businesses, but they are likely to be similar to each other (in thermostat presence and lifetimes); however, they may be expected to differ from larger firms, at least in the number of thermostats they have. We were able to stratify on employment size at the site, which we used to reflect square footage, a variable we *did* expect to have an effect on at least the number of thermostats at the site. We purchased a random sample of each of four business sizes (less than 20 employees, 20-99, 100-499, and 500 and more employees). There are many thousands of the smallest ones, and they become progressively less numerous as the employment categories increase. We purchased increasing *proportions* (not numbers) of sample from the larger firms so we could be reasonably certain the population in that group would be represented by multiple respondents. This stratification technique can improve the quality and robustness of the database.

Figure 2.2 later in this chapter shows the sample sizes per group, response rates, and estimated "counts".

Survey Approach: Users called up the website and clicked on the labeled button to launch the survey. A web survey was selected because it provided several advantages.

- Drawings / pictures can be incorporated for clarification of issues – particularly identification of mercury- vs. non-mercury containing thermostat types;
- Respondents can complete the survey at their convenience (rather than only during phone hours, which helps with small businesses),
- It can be distributed easily and inexpensively, and the survey is fielded quickly,
- Skip patterns are automatic - so errors do not arise and the survey can be shorter or longer based on specific responses;
- Data is automatically entered into the computer – no separate keypunch entry costs (and errors.)

[8] Purchased from InfoUSA, a well-known vendor.

[9] Or, if there were, we would uncover it as part of the work; it was not something known ahead of time in a way that would support complex residential sampling. In energy end-use surveys, the residential sector is rarely stratified beyond single- vs. multi-family.

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- 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; and the data can be analyzed in "real time" and the survey "left active" and analyzed again when more responses have been received.

The survey was distributed via postcard to the sampled homes and businesses, providing a link to a web survey (on SERA's neutral website "garbageandrecyclingsurvey.com"), with two email follow-ups to the business sample, as their response rate had lagged. Both the postcards and emails also directed recipients to a toll-free number if they preferred to complete the survey by phone (which removes a barrier for elderly households). The postcard and emails also notified recipients that filling out the survey entered them into a lottery to win one of several Kindles[10].

Questionnaire content: The questionnaire (or "survey instrument") collects the key analytical data of interest, as well as relevant demographics or "firm-o-graphics", which allows us to match back to the stratification and weighting strategy, and then match response proportions against the initial database or against published "census" or other data. The questionnaire is included in the Appendix. The key analytical information solicited in the questionnaire included:

- Whether there are any thermostats in buildings.
- Type of thermostats (we included photos of various types, and asked respondents to classify thermostats into square, round, snap, digital, or lever or other, as shown in the photo in the executive summary).
- How many thermostats in buildings of the type(s) of interest; whether each is still functioning (&)[11]
- Year built (*); best estimate of year thermostats were installed, and, if any were removed, when removed.
- 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.
- Firmographic data: type of business, estimated square footage, number of employees.

Information on number of thermostats, by type, is all that is needed to establish "A", the inventory. However, the questions on age and failures are needed to support the work in "C" and "D".

Sample Size: Getting sufficient respondents is generally a problem with surveys (and general survey confidence levels associated with variations in response are listed 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[12] is not very different. No matter how big the total households (within a fairly large band),

[10] We have found this prize works well for both the residential and commercial sector. The cost of even several dozen Kindle players is still many times less than the cost of a large scale phone survey.

[11] The features marked with asterisks (*) were identified as strong explanatory factors for the King County work. The data collection elements marked with ampersands (&) represent those needed to support measure retention / removal analyses.

[12] 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.

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the sample sizes needed are similar.[13] However, samples sizes for EUL surveys are an especially large problem. General responses are satisfactory for the inventory portion of the project, but to estimate lifetimes and turnover, you need "failures and removals", which happen in (or are known about in) only a portion of the responding businesses and homes. We obtained more samples to assure we have enough that failed / were removed. Generally, however, more data (rather than less) help predictive modeling work.

Figure 2.1: Computation of Sample Sizes and Resulting Accuracy / Confidence in Responses

IF the community's population (homes or comm'l bldgs) is…	95% confidence		90% confidence	
Computed responses needed for accuracy of…	+/-5%	+/-10%[14]	+/-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

After comparing the response rates by county to census data (to confirm that we received responses that were reasonably representative of the State), we estimated the "average" number of thermostats for each respondent type, as shown in Figure 2.3 (single family, multifamily, and the commercial strata). To develop correct estimates for the subtotals and total (residential, commercial, total), we used census "population" figures to identify how many non-respondents each of the respondents is "standing in" for (the implied "weight" is included in the Figure). These are the raw survey-based computations. Additional field and camera validation work was conducted to allow us to adjust the results based on possible sources of respondent error (counts and types of thermostats).

The survey responses received –463 residential (with thermostat data) and 218 commercial – provides accuracy levels of, respectively, +/-4.6% and 6.7% at the 95% confidence level.[15]

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

[14] Also equals +/- 7% at 90% confidence.

[15] At the 90% confidence levels, these figures are, respectively, +/- 3.78% and +/-5.6%. For analyses in which 187 commercial responses were used, the accuracy is +/-6% at 90% confidence and +/- 7.2% at 95% confidence.

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Figure 2.2: Sample Size, Responses, and Estimated "Count" of Thermostats

Category -- with Counts from Data Purchase Firm	IL Sample Purchased	IL survey responses - all	IL survey responses including # of Therm	Response Percent of Purchased Sample	Total Units from Census and Business Statistics (Establishments, thous)
Single Family HHs (Grp1)	9,990	434	414	4.3%	3,554.5
Multi-Family HHs (2)	2,010	58	49	2.9%	1,742.8
Small Business (<=19 empl) (3)	4,148	97	86	2.3%	252.1
Medium Business (20-99 empl) (4)	4,135	70	63	1.7%	42.2
Large Business (100+ empl)(5&6)	3,617	46	38	1.3%	18.1
Residential Total	12,000	492	463	4.1%	5,297.3
Commercial total[16]	11,900	274	187	2.3%	312.4
Grand Total	23,900	766	681	3.2%	5,609.8

Figure 2.3 Computation of Estimated Inventory of Thermostats on Illinois Walls

Category -- with Counts from Data Purchase Firm	Total Units from Census and Business Statistics (Establishments, thous)	Number of Thermostats, Average by Class[17]	Estimated Total thermostats in IL Buildings (thous)
Single Family HHs (Grp1)	3,554.5	1.25	4,443
Multi-Family HHs (2)	1,742.8	0.96	1,673
Small Business (<=19 empl) (3)	252.1	3.13	789
Medium Business (20-99 empl) (4)	42.2	8.57	361
Large Business (100+ empl) (5&6)	18.1	25.41	460
Residential Total	5,297.3	1.15	6,116
Commercial total	312.4	5.16	1,611
Grand Total	5,609.8	1.38	7,727

To provide a context for the results from the Illinois work we benchmark the findings with the most comparable work available in the literature – the results from the 2009 California study (SERA 2009)[18]. The comparison in Figure 2.4 shows the averages and the "normalized" results (that is, results normalized to the population or size of the state) from these two states are similar. The study estimates that there are 2.56 times as many thermostats in California buildings, in a state that is 2.95 times as large (in population) as Illinois. Given climate differences, this direction for the difference is the direction expected.

[16] An additional 61 commercial surveys were returned, but their business size class was not provided. These respondents could not be used in analyses that were weighted by class. Thirty-one of them answered questions about number of thermostats.

[17] 90% Confidence intervals are, respectively, (1.17-1.33), (0.82-1.10), (2.48-3.78), (3.76-13.38), (17.03-33.79). The resulting thermostat totals for low vs. high ends of the confidence intervals are 6.68 million to 8.77 million.

[18] Skumatz, Lisa A., Mercury-Containing Thermostats: Estimating Inventory and Flow from Existing Residential & Commercial Buildings- A Study to Meet Requirements for State of California Thermostat Recycling Legislation, Skumatz Economic Research Associates, Superior, CO, for TRC, December 28, 2009.

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Figure 2.4 Comparison of Illinois Results to Findings from Similar Study in the State of California (SERA, 2009)

	Illinois	California	Ratio (CA over IL)
Average number of thermostats			
Per Household	1.15	1.17	1.02
Per business	5.16	5.6	1.09
Overall (weighted average of household and business)	1.38	1.5	1.09
Total thermostats in the State	7.7 million	19.8 million	2.56
State Population	12.9 million	38 million	2.95

This estimate is refined below, adding "corrections" identified in our validation work. Then the information on the percent that contain mercury is applied to produce an estimate of the number of inventory of thermostats in the State with mercury.

Validation Efforts

Three validation efforts were conducted. All contribute to the computations of Steps "A and B" – identifying the "count" of thermostats by type, and the percent that contain mercury.

Validation 1 – On-site: NRDC sent trained staff to complete on-site visits to a set of specially selected respondent buildings (residential and commercial) as possible. They completed on-sites at 46 survey respondent sites (residential and commercial).[19] Their trained staff inspected thermostats to determine whether they contained mercury or not, and checked whether the sample of survey respondents were accurate in their report of the number and type of thermostats in their home or establishment. NRDC staff photographed open thermostats to document the presence of mercury in the thermostats. SERA selected the sample from among buildings that responded to the survey (residential and commercial, randomly selected within geographic clusters[20] to manage travel costs). This provided valuable information and 'correction factors' to be applied to the averages and counts estimated from the survey data.

Validation 2 – Camera Phone: SERA contacted a random set of 33 respondents around the State (by phone and email) and asked them to take a digital photo of each "type" of thermostat they had, and re-count the number of thermostats on their walls.[21] In return, for those sending

[19] The on-site validation sample included buildings in the following communities: Addison, Alton, Carbondale, Catlin, Chicago, Cicero, Collinsville, Elk Grove Village, Elmwood Park, Gilberts, Graystake, Huey, Joliet, Lemont, Lena, Maryville, Murphysboro, Naperville, Palatine, Park Ridge, Rantoul, Roselle, Rosemont, Rushville, St. Charles, Wataga, West Union, Westmont, and Wheaton.

[20] Some sampling preference for non-digital thermostats was introduced into the sample, as it was known that digital thermostats would not contain mercury, and the primary objective of the on-site surveys was to inspect for the presence of mercury. Validation of number and visual types was checked through the camera survey, providing additional confirmation on digital models.

[21] The camera-phone validation sample included buildings in the following communities: Auburn, Aurora, Benton, Brookfield, Chicago, Darien, Des Plaines, Downers Grove, Edwardsville, Forest Park, Homewood, Lake Villa, Lake Zurich, Macomb, McHenry, Morton, Mundelein, Ottawa, Plano, Riverton, Robinson, Rock Island, Rockford,

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in photos, gift certificates to Starbucks were sent. This sample included all types of thermostats. This supported a validation of the "count" against their response, and the types they reported as well. Again, this provided information on correction factors for the survey data.

Validation 3 – Contractor Interviews: SERA interviewed a sample of 30 Illinois HVAC contractors around the state. We asked about the different types of thermostats, when and where they tended to be installed, and estimates of the percent of thermostats that contain mercury. These interviews provided extra information to inform ranges and estimates for the inputs used in the computations, feedback on the relative ages of various types of thermostats (which were the older technologies, etc.), and provided additional understanding of thermostat practices.

On-Site Validation Results – Percent of Thermostat Models Containing Mercury

Figure 2.5 tabulates the results of the on-site validations by NRDC of the percent of thermostats inspected that contained mercury. The samples sizes for the on-site mercury inspections are strong (at least on the commercial side). We elected to use the commercial sector estimates across the board, rather than applying the small-sample residential values. When weighted by "type" based on the survey responses, the overall percent of mercury-containing thermostats on walls in Illinois is estimated to be 24.7% (see Figure 2.8). When asked about the percent of all thermostats in place on walls that contained mercury, the (limited) sample of contractor responses had a median of 22.5% and an average of 29%, providing another source of confidence in the general range of the calculated average.

Figure 2.5: On-site Validation Results: Percent of Thermostats Containing Mercury, by Type

On site Validation	Commercial-on site	Residential - on site	Weighted Average (80% residential, 20% com'l)	Simple average
Square: % with Mercury (34 inspected)	70%	100%	94%	85%
Round: % with Mercury (28 inspected)	95%	100%	99%	97.5%
Digital: % with Mercury (136 inspected)	0%	0%	0%	0%
Snap: % with Mercury (34 inspected)	3%	NA	1%	1.5%
Lever / Dial / Other: % with Mercury (57 inspected)	9%	NA	2%	4.5%

The results show that the largest share of mercury-containing thermostats on Illinois walls are of the round and square types. Based on these results, the total thermostats that are mercury-containing were estimated somewhat conservatively[22] using the following method (the lesser of the weighted or simple averages above):

Schaumburg, Springfield, Streamwood, and Volo. The camera validation allowed us to confirm classifications, and check the consistency of the count of thermostats on the walls.

[22] Note that the estimates of total potential mercury-containing thermostats are reduced by the omission of thermostats located in common areas of multi-family buildings. It was not considered feasible to ask residents in these buildings to inspect the hallways and common areas outside their unit.

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- 85% of total estimated square models are assumed to contain mercury;
- 97.5% of round thermostats are assumed to contain mercury;
- 1% of snap, and 2% of lever / dial models are assumed to contain mercury;
- No thermostats installed since 2009 (less than 5 years old) are assumed to contain mercury.[23]

Validation Findings on Survey Counts

Figure 2.6 compares the total number of thermostats that a sample of business and household respondents provided on the survey. Some of the sample counts from the sample were verified during the on-site work, and others were validated by the camera validation approach. The results show that the total counts of surveys were quite close to those reported in the survey, with only a 2% correction factor needed to bring commercial thermostat counts into agreement with the verified totals. This correction factor is applied in the computation of corrected totals in Figure 2.7 below.

Figure 2.6: Validation Results on Total Count of Thermostats, Total and by Thermostat Type

	Residential Total	Commercial Total
Number of thermostats reported by survey	40	318
Number of thermostats found in on-site and camera validations	40	312
Resulting "adjustment" factor for totals	100%	98%

We also reviewed the on-site and camera feedback on the accuracy of reports on the types of thermostats in place, and checked whether any inaccuracies affected the estimated total of mercury vs. non-mercury-containing thermostats. There were some mis-classifications among the more than 150 commercial installations validated. When we reviewed the effect on the computed number of mercury-containing thermostats included in Figure 2.8 (total 1,910), the effect was to reduce mercury containing thermostats by 6% (See Figure 2.7). There were also some mis-classifications in residential thermostats; however, relatively few residential validations of these types of thermostats were completed (fewer than 20). The direction indicated by residential mis-identifications was to increase the number of mercury-containing thermostats (by a larger number). Because of the relatively small sample on which these figures are based, and in an effort to be conservative, we omit this correction factor. The combinations of adjustments are addressed in the corrected totals in Figure 2.9. Graphics of the survey responses on types of thermostats in residential and commercial buildings in Illinois are presented in Figure 2.10.

Figure 2.7: Validation Results on Total Count of Thermostats, Total and by Thermostat Type

	Total
Total number of mercury-containing thermostats reported from survey (Figure 2.8)	1910
Number of mercury-containing thermostats correcting for mis-identifications of type from commercial validations	1,790
Resulting "adjustment" factor for totals	94%

[23] The data saw a 2% reduction in the total mercury-containing thermostats that had ages reported when those newer than 5 years were removed.

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Figure 2.8: Calculation of Inventory of Mercury-Containing Thermostats in Buildings in Illinois

Percent by Thermostat Type and Building Type	Square	Round	Digital	Snap	Lever/ Dial	Other	Total # Thermo-stats (thous)
Single Family (Group 1)	11.3%	16.4%	68.8%	2.2%	1.3%	0.0%	4,443
Multi-Family (2)	16.1%	7.2%	67.9%	1.8%	3.6%	3.6%	1,673
Small Business (3)	21.7%	11.8%	56.3%	3.3%	6.6%	0.3%	789
Medium Business (4)	9.8%	5.8%	34.5%	36.5%	13.3%	0.0%	361
Large Business (5)	1.6%	32.2%	51.0%	0.8%	12.7%	1.8%	407
Largest Businesses (6)	0.0%	0.0%	73.8%	26.3%	0.0%	0.0%	52
Residential Total Thermostats, Thousands	771	849	4,193	128	118	60	6,119
Commercial Thermostats, Thousands	213	245	815	175	152	10	1,609
Total Thermostats in Bldgs, Thousands	985	1,094	5,007	303	270	70	7,728
Percent with Mercury (computed from on-site visit inspections, selected averages)	85%	97.5%	0%	1%	2%	0%	
Total Mercury Thermostats, Thousands	837	1,067	-	2	5	-	1,910
						Percent Mercury	24.7%

Figure 2.9: Adjustments to Mercury Thermostat Counts, and Revised Total, Illinois (thousands)

	Initial (Figure 2.6)	Reduce Com'l Overall 2%	No correction applied based on mis-identification of thermostat types (conservative assumption/small sample)	Remove 2% of mercury reported 5 years or newer	Revised Total[24]
Estimated Mercury-Containing Thermostats	1,910	1,902	1,902	1,864	1,864
Estimated Non-Mercury Thermostats	5,818	5,794	5,794	5,832	5,832
Estimated Total Thermostats	7,727	7,696	7,696	7,696	7,696
Mercury Percent of Total	24.7%	24.7%	24.7%	24.2%	24.2%

[24] The 90% confidence ranges for mercury, non-mercury, and total thermostats are, respectively, (1603-2106), (5077-6668), and (6680-8774), respectively, based on the confidence intervals for the thermostat means.

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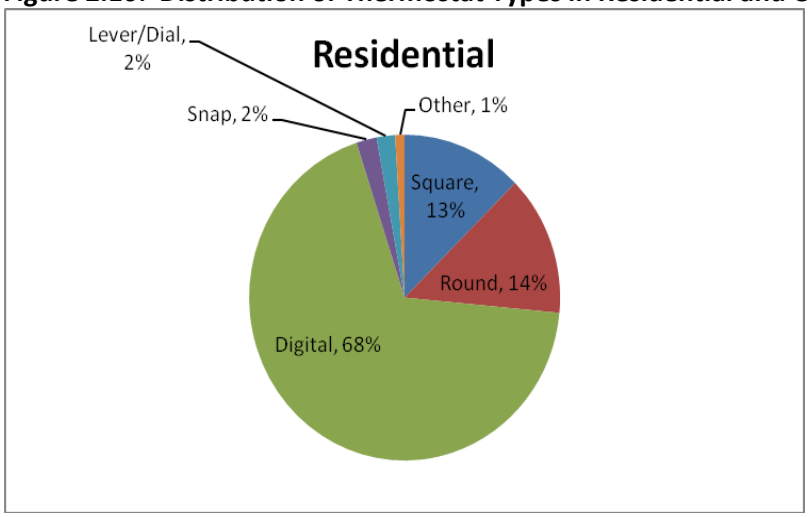
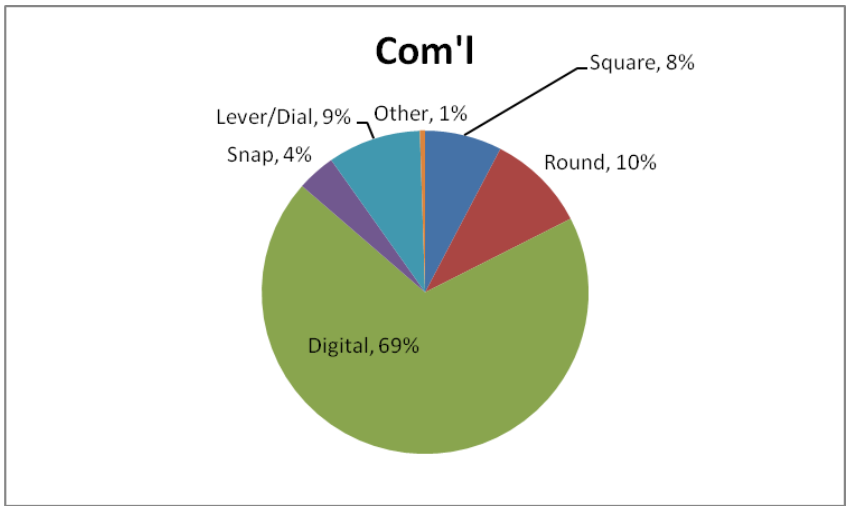
Figure 2.10: Distribution of Thermostat Types in Residential and Commercial Buildings in Illinois





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3. Conducting Steps C & D: Estimating the Flow of Mercury-Containing Thermostats from Illinois Buildings

This part of the work involved two steps that, together, provide a prediction of the lifetime and annual "flow" of mercury-containing thermostats out of Illinois buildings.

Step C: This analysis, based on the methods used to predict measure lifetimes and removals of all kinds of energy using equipment, estimates "hazard" functions that relate to the decay and removal of equipment (which may arise from either ceasing to function or removal due to remodeling / replacement). The statistical technique uses information from the lifetimes of measures that have already been removed, *and* the length of time currently in-place thermostats have functioned without removal, to predict how long the remaining equipment will last. The estimation provides an EUL (effective useful lifetime, the median life, or the age at which half of the thermostats would still be expected to be functioning and half failed). The estimation work also provides the annual percent of failures, or an annual flow of removals in percentage terms. In simplistic terms, we then multiplied these annual failure / removal rates times the equipment in place (estimated above) to get the actual number expected to be removed each year from the residential vs. the commercial sectors.[25]

Using data from the survey on years thermostats were installed and removed (or just installed), we tested different statistical models, comparing the performance of different decay functions (specifically log normal, log logistic, Weibull, exponential, and gamma, distributions) to identify the best "fit". The selected Gamma-based model performed best on the basis of a comparison of log likelihood statistics. The resulting distribution, showing the percent of cumulative failures over the years, is provided in Figure 3.1. The figure implies that the median life of thermostats is about 27.5 years[26]; that is, half the thermostats installed are would be expected to still be in place and functioning 27.5 years *after installation*, and the other half would have been removed.

[25] Step "D" clarifies the refinement needed to this last statement to obtain the final annual estimate.
[26] This is the same value derived in the California work.

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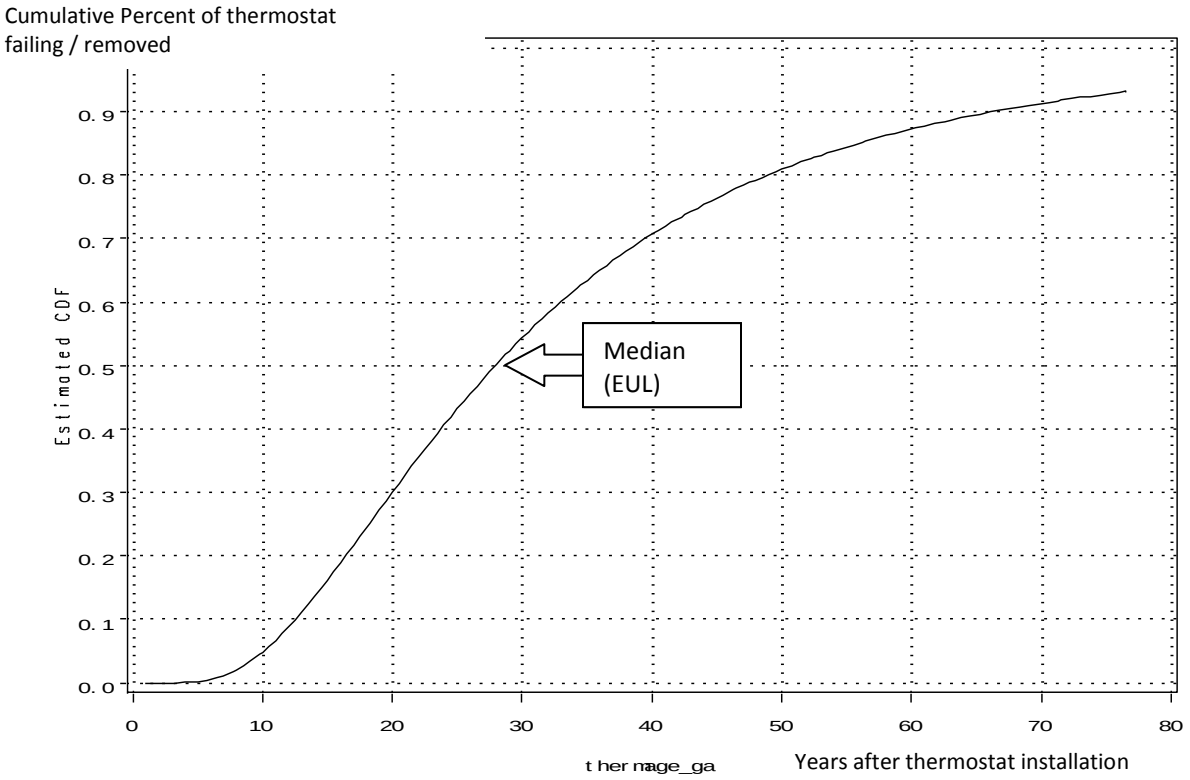
Figure 3.1: Percent of Thermostats Failed / Removed by Age of Thermostat – For One Cohort of Thermostats

(vertical axis is share of thermostats failed, horizontal axis provides number of years expired; Gamma distribution)



The contractor survey also asked about the decades in which different types of thermostats were installed, and about how long they expected thermostats to last in residential and commercial installations. The results are shown in Figure 3.2. The results indicated an industry progression of installations by type moving from round as the oldest, to square and lever, to snap to digital, with the oldest installations representing those most likely to contain mercury. Median lifetimes upwards of 20 years were expected for the equipment, with the exception of digital programmable thermostats, which contractors seem to expect to have shorter lifetimes. In two cases (round and snap), the respondents were divided about their lifetimes in commercial buildings. This difference in installation dates of about 20-30 years between square and round vs. their non-mercury-containing replacements is generally consistent with the differences in average and median ages noted in this section.

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Figure 3.2: Illinois Contractor Responses on Thermostat Installation Phases and Lifetimes
(based on 30 responses)

Thermostat Type	In which decade(s) were these installed?	How many years do they last in the typical HOME? At what age are HALF gone from use?	How many years do they last in the typical COMMERCIAL building? At what age are HALF gone from use?
Square	1970s (50s-80s)	20-27 yrs	20-23 yrs
Round	1960s (50s-80s)	20-31 yrs	15-19 or 28-31 yrs
Digital	1990s (90s-00s)	12-15 yrs	12-15 yrs
Snap-type	1980s (70s-80s)	20-23 yrs	12-15 or 20-23 yrs
Other Lever/dial-type	1970s (70s-80s)	12-23 yrs	n/a
Other	n/a	8-15 yrs	n/a

Step "D" - Refinements/ Implications and Final Estimations

One last step was required. The hazard function above shows how many of, say, one hundred thermostats, installed at the same time, will still be in place (or not removed) after 1, 10, 20, or 40 years of operation. However, our case is somewhat different. In our estimated statewide inventory, we have many cohorts of many types of thermostats, installed (or "starting") in many different years (see Figure 3.3).

Figure 3.3: Distribution of Age of Thermostats on the Wall, by Percentiles (5% increments)

Percentile Groupings	Age for Mercury-Containing Thermostats	Age for Non-Mercury-Containing Thermostats
1% of thermostats	10.5 years	1.5 years
5% of thermostats	12.5	1.5
10% of thermostats	12.5	1.5
15% of thermostats	14.5	1.5
20% of thermostats	17.0	4.5
25% of thermostats	21.0	4.5
30% of thermostats	22.5	6.5
35% of thermostats	26.0	6.5
40% of thermostats	26.0	6.5
45% of thermostats	29.5	6.5
50% of thermostats (median)	31.0	8.5
55% of thermostats	33.0	10.0
60% of thermostats	37.0	12.5
65% of thermostats	38.0	15.0
70% of thermostats	38.0	20.0
75% of thermostats	38.0	21.0
80% of thermostats	43.5	25.5
85% of thermostats	48.0	31.0
90% of thermostats	54.0	31.0

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Percentile Groupings	Age for Mercury-Containing Thermostats	Age for Non-Mercury-Containing Thermostats
95% of thermostats	63.0	36.5
99% of thermostats	63.0	58.0
Mean (and 90% confidence interval	32.1 (29.7-34.6)	14.2 (13.4-15.0)

The actual computation of annual flows of mercury-containing thermostats from Illinois 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 classified thermostats into "mercury-containing" and "non-mercury-containing", based mainly on type (97.5% of round, 85% of square were mercury, with small additional totals from lever and snap). Second, we classified all thermostats with ages less than five years as non-mercury, since mercury models were banned in 2009. Then we divided the total inventories of existing mercury and non-mercury thermostats into cohorts based on 5% groupings (a finer distinction than "quartiles")[27], ranked by age of the thermostats currently installed.[28] The figures, displayed in Figure 3.3, show that the youngest 25% of mercury-containing thermostats are about 21 years old, but the youngest quarter of non-mercury-containing models were less than 5 years old. The average age of mercury-containing models on the wall is 32.4 years (median, or half, are 31 years or older). For non-mercury-containing models, the average age is 14 years, and the median is less than 9 years old.

Using the bar chart approximation to the fitted lifetime curve (Figure 3.4), 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 54 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.[29] We used the same approach for non-mercury-containing thermostats, as they were also installed over a period of years, not one point in time. The estimated results are presented in Figure 3.5 and are shown graphically below.[30]

[27] We ultimately modeled the flows based on quartiles representing every 5% of the thermostats; 5%, 10%, 15%, etc. This helped "smooth" the flows considerably, compared to using batches representing 25% of thermostats.
[28] 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.
[29] Based on lifetime expectations, not including adjustments for temporary economic circumstances.
[30] The Excel approximation to the estimated model formula varies slightly at the outer years to make the function get to 100%.

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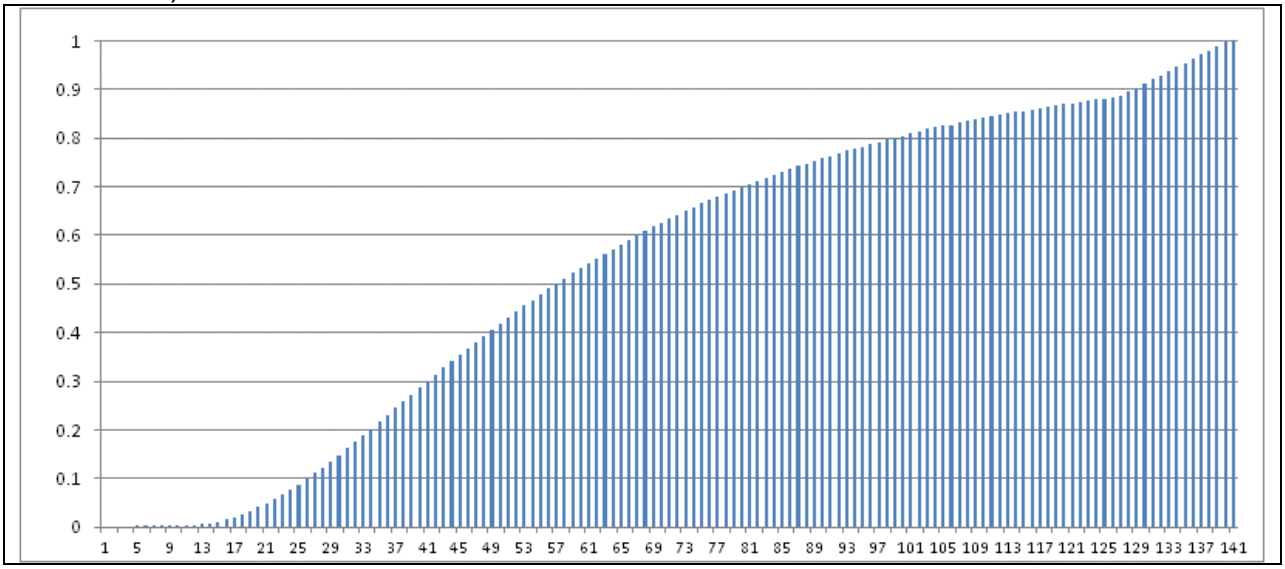
Figure 3.4: Excel™ approximation to the Measure Life Distribution Function

(the horizontal axis is ½ years; the vertical axis represents the cumulative percent of thermostats that have failed or been removed)



Notice that the outflows in Figure 3.5 below do not monotonically decrease over time; there are increases and decreases. This is largely because the curve is not linear. The convex and concave portions of the curve imply the incremental outflows will not be constant over time. The annual results from these computations are provided below, in Figure 3.5. The estimate provided in the Executive Summary is computed from the five year averages from this table, presented below as Figure 3.6.

Figure 3.5: Flow of Illinois Mercury-Containing Thermostats assuming Multiple 5% Cohorts of Mercury- and Non-Mercury-Containing Thermostats

Year	Mercury-containing thermostat outflow, by year (thousands)	Non-Mercury thermostat outflow, by year (thousands)	Cumulative Percent of Mercury Models Removed
2014	108	119	6%
2015	106	122	11%
2016	104	129	17%
2017	101	135	22%
2018	98	140	28%
2019	96	152	33%
2020[31]	84	155	37%
2021	61	160	41%
2022	56	162	44%
2023	63	164	47%
2024	61	164	50%
2025	59	161	54%

[31] The last year before the Illinois Mercury Thermostat Collection Act sunsets.

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Year	Mercury-containing thermostat outflow, by year (thousands)	Non-Mercury thermostat outflow, by year (thousands)	Cumulative Percent of Mercury Models Removed
2026	59	154	57%
2027	55	152	60%
2028	52	150	62%
2029	53	143	65%
2030	45	141	68%
2031	44	137	70%
2032	42	133	72%
2033	43	131	75%
2034	44	123	77%
2035	40	117	79%
2036	32	114	81%
2037	32	109	83%
2038	32	106	84%
2039	42	102	86%
2040	39	102	89%
2041	38	102	91%
2042	37	99	93%
2043	36	97	95%
2044	39	93	97%
2045	33	89	98%
2046	22	103	100%
2047	20	88	100%
2048	0	82	100%
2049	0	80	100%
2050	0	77	100%

Figure 3.6: Estimated Five Year Averages of Outflows of Mercury-Containing Thermostats from Illinois

5-6 Year Periods	Mercury-containing thermostats (thousands)	Non-Mercury-containing thermostats (thousands)	Mercury Thermostats: Cumulative Percent flowed out	Non-mercury thermostats: Cumulative Percent flowed out
2014-2019	102	133	33%	14%
2020[32]-2024	65	161	50%	27%
2025-2029	56	152	65%	40%
2030-2034	43	133	77%	52%
2035-2039	36	110	86%	61%
2040-2044	38	99	97%	70%
2045-2049	12	88	100%	77%

[32] The last year before the Illinois Mercury Thermostat Collection Act sunsets.

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5-6 Year Periods	Mercury-containing thermostats (thousands)	Non-Mercury-containing thermostats (thousands)	Mercury Thermostats: Cumulative Percent flowed out	Non-mercury thermostats: Cumulative Percent flowed out
2050-2054		65		83%
2055-2059		51		87%
2060-2064		39		91%
2065-2069		32		93%
2070-2074		41		97%
Total to 2074	1,864	5,655		

Sunset Provision Implications

The outflow data presented in Figures 3.4 and Figure 3.5 indicate that only 697,000 of the estimated 1.86 million mercury thermostats (37%) remaining in Illinois are subject to the requirements of the Illinois Mercury Thermostat Collection Act before the legislation sunsets. The sunset provision was presumably drafted to reflect stakeholder expectations that the legislation would address a majority of the mercury thermostats in the State, and that fewer mercury thermostats would remain by 2021. The information in Figure 3.5 indicates that:

- More than 50% of thermostats would not be available for removal until 2025 (50% in 2024);
- It would take until 2030 to expect two-thirds of the mercury thermostats to be available for removal; and
- Outflow of 80% of the mercury thermostats available for recovery doesn't occur until 2035.

Actual recovery of these percentages of thermostats would require 100% capture of the outflowing units.

Given the sunset provision in existing law, we performed a "sunset flow analysis" where we assumed the majority of the remaining mercury thermostats (51%) would be collected before 2021. The number that would need to be collected annually to achieve that outflow total is presented below.

There are two issues related to this analysis. The natural outflow of thermostats would need to be accelerated by some artificial means – perhaps incentives or bounties, perhaps programs cooperating with the electric / gas utilities, or perhaps other policies or requirements. Second, if the goal is set to actually achieve *recovery* of a percentage of thermostats (not just achieve outflow of a specific percent that are then *available* to recover), an additional (recovery) variable or assumption is introduced. Combinations of these factors to achieve recovery of 50% of thermostats, and 75% of thermostats, within the sunset period, are presented in Figure 3.7 below.

Recovery of half the available thermostats by 2020 with normal or expected outflows is not possible. Based on the analysis, to *recover* at least 50% of the mercury-containing thermostats coming off the wall by the sunset year (2020) will require one of the following scenarios:

- Complete capture (100%) of all mercury-containing thermostats flowing off walls IF policies achieve 35% higher annual outflows than estimated as normal (achieves 50% by 2020).

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- Capture at least 84% of all mercury-containing thermostats flowing off walls IF policies achieve 50% higher annual outflows than estimated as normal.
- Capture at least 67% of all mercury-containing thermostats flowing off walls IF policies achieve 100% higher annual outflows than estimated as normal (twice the normal expected flow).

Figure 3.7: Sunset Analysis – Alternatives to Achieve 50% Recovery of Mercury-Containing Thermostats from Illinois

	50% of Mercury thermostats available by 2020 (35% more than expected natural outflow)				60% of Mercury thermostats available by 2020 (62% more than expected natural outflow)				75% of Mercury thermostats available by 2020 (doubling the expected flow)			
Recovering X% of Mercury Thermostat Outflow available==>	If 50% recovered	If 67% recovered	If 75% recovered	If 100% recovered	If 50% recovered	If 67% recovered	If 75% recovered	If 100% recovered	If 50% recovered	If 67% recovered	If 75% recovered	If 100% recovered
2014	73	98	109	146	87	117	131	175	108	145	162	216
2015	71	96	107	143	86	115	129	172	106	142	159	212
2016	70	94	106	141	84	113	127	169	104	140	156	209
2017	68	91	102	136	82	110	123	164	101	135	152	202
2018	66	89	99	132	79	106	119	159	98	131	147	196
2019	65	87	97	130	78	105	117	156	96	129	144	193
2020	57	76	85	113	68	91	102	136	84	112	126	168
Total Recovered	471	631	706	941	565	757	847	1,129	697	934	1,046	1,394
Total Hg Thermo-stats on Walls	1,876	1,876	1,876	1,876	1,876	1,876	1,876	1,876	1,876	1,876	1,876	1,876
Percent Recovered	25%	34%	38%	***50%***	30%	40%	45%	***60%***	37%	***50%***	***56%***	***74%***

According to the estimates, to achieve recovery of at least 50% of the mercury thermostats in place by the 2020 sunset of the law, industry will need to gear up a program that identifies and recovers an annual average of 134,000 mercury-containing models (from all of the outflows) for each of the years 2014-2020. Given the flow patterns, and the unlikelihood of achieving this level of progress immediately, recovery numbers in specific years may make capacity figures of upwards of 190,000 necessary to achieve recovery of even half the mercury-containing equipment by 2020, and that assumes policies or programs in place to draw significantly-enhanced numbers of existing thermostats off the walls in Illinois.

Alternatively, scenarios can consider revisiting the sunset date. Extending the sunset to 2035, with an assumption of capture of almost two-thirds of normal available flow would account for half of the existing models, or recovery of three-quarters of all the mercury models available prior to a sunset of 2030 would similarly recover half the mercury-containing equipment. The annual flow information in this report will support computation of the years and program size needed to achieve a desired recovery policy goal, whether that is 50% or some other mercury recovery target that is established.

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Appendix A: Literature Review (in Function-Based Context)

There are two key elements to the computation of the denominator of a collection rate for mercury thermostats:

- Step 1: Estimating the "number" of thermostats removed annually (ideally, allowing for change over time as building stock and equipment ages); and
- Step 2: Estimating the percentage of those thermostats removed each year that contain mercury (allowing for change over time to reflect variations based on the age and technology of thermostats installed).

In this appendix, we review the options for these steps, and examples of the literature that attempted to use each option, specifically focusing on four studies:

- King County, "Summary Report: Mercury Thermostats in Commercial Buildings in King County" 11/1/2005, Gail Savina.
- *Mercury-Containing Thermostats: Estimating Inventory and Flow from Existing Residential & Commercial Buildings, Skumatz Economic Research Associates, for Thermostat Recycling Corporation, 2009.*
- "*Measuring Performance of Mercury Thermostat Collection Programs: Approaches and Analysis* ", the Product Stewardship Institute (PSI), 2010.
- *North American HVAC Thermostat Markets*, by Frost & Sullivan, 2003.

This review is similar to a chapter of the PSI study; the chapter was authored by SERA and is adapted here.

Step 1: Determine the number of thermostats coming off the wall.

The following four methods have been used to estimate the number of thermostats coming off the wall:
(1) on-site inspection of buildings and thermostats on the premises (e.g., King County, WA);
(2) occupant reporting of buildings and thermostat ages (e.g., SERA/TRC report);
(3) replacement sales data (using Frost and Sullivan industry data); and
(4) interviews with contractors (PSI report).

The strengths and weaknesses of using each of these three options are summarized in Table A.1 below. Of the three approaches, on-site inspection of a sample of buildings is considered to be the most reliable because it includes direct observation of number, type, and potentially age / failure / replacement by knowledgeable professionals; however it is also the most expensive and time-consuming.[33] By contrast, relying on sales data is less expensive, although the data are not collected specifically to determine the number of thermostats coming off the walls (or coming off the walls in one particular state) and, therefore, require additional assumptions to obtain an estimate. The occupant survey approach can

[33] The statistical reliability of this approach depends on the sample design, sample size, and the degree to which sites that allow the inspection are representative of the overall population of sites.

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provide a statistically quantifiable level of confidence in the data at a reasonable cost but introduces uncertainty regarding the accuracy of occupant-reported data.

Figure A.1: Options for Estimating the Number of Thermostats Coming Off the Wall (Step 1): Strengths and Weaknesses

Option	Strengths	Weaknesses
On-site inspection & analysis	• Reliably observed data • Can collect data for both steps 1 and 2 at the same time. • Provides robust data for projecting changes in thermostat removal over time • Can identify share that is residential vs. commercial if needed	• Relatively expensive and labor intensive to obtain sample large and diverse enough for robust statistical reliability • Must identify suitable "population list,"[34] to sample from; design sample, and check / control for potential non-response bias • Analysis is somewhat complex
Occupant survey responses & analysis	• Data collected based on on-site inspection of equipment; reasonable, but not infallible data • Can collect data for both steps 1 and 2 at the same time. • Provides robust data for projecting changes in thermostat removal over time • Can identify residential vs. commercial sources if needed • Fast to collect/get responses	• Less expensive than on-site data collection, but still requires significant resources • Must identify suitable "population list," design sample, and check / control for potential non-response bias • Analysis is somewhat complex
Sales data	• Easy analysis • Relies on industry supplied data and expert judgments	• Extrapolating national sales/shipment data to a statewide basis does not account for state-specific conditions (e.g., age of building stock, climate, etc.) • Requires purchase of industry report on periodic basis, which requires funding. • Does not provide data for projections over time • Data sources are incomplete (not all firms "report") • No data to support step 2
Contractor Surveys	• Use of "expert" knowledge • Relatively easy to obtain "sample" of contractors from purchased data, Better Business Bureau, etc. • Can concurrently collect information to support Step 2 (percent that contain mercury)	• Very weak response rates, even when partnering with industry associations; poor sample size • Busy, hard to contact, "varied" knowledge and experience; some opinions don't "jibe" with numbers.

[34] The issue of "population list" is important, and carries over to all surveys described in this document. A sample is drawn from a population list, and if the survey is performed in a way that meets various statistical criteria, the sample will adequately describe the specific population from which it was drawn. That means that any limitations or disconnects in the link between the population list obtained and what one is actually trying to describe must be considered.

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a. On-site Inspection and Analysis

In 2005, King County conducted a study of mercury thermostats in commercial buildings, and inspected 1% of the commercial buildings in King County, equal to about 346 structures. King County found that the distribution of mercury thermostats was strongly correlated with building age, and that buildings that were built in the period 1953-1980 were the most likely to contain mercury thermostats. The study found that, on average, 18% of all thermostats inspected contained mercury. Since this study was limited to commercial buildings, it cannot be used to estimate the number of thermostats in residential settings. Also, the study focused on measuring the existing stock of mercury thermostats and did not address how quickly those thermostats were coming out of service. The study provided the basis for developing a mathematical model of the relationship between building characteristics (age, size, heat source, predominant use) and the presence of mercury thermostats. This model could potentially be adapted by other states to estimate the number of mercury thermostats available for collection in commercial buildings in their own states. The data collected in King County, however, may not be representative of other states due to a variety of factors. As noted previously, replacement rates and the fraction of thermostats that contain mercury are likely to be lower in King County than in eastern states.

Although on-site inspections are time and resource-intensive, if resources are available - *and a high level of confidence is needed* - it would be possible to draw a sample of buildings in the state or local area and inspect them for the information needed. Based on the information collected from a combination of site visits and occupant interviews (which are needed for age, change-outs, etc.), a model addressing thermostat usage, building parameters, and building stock would then have to be developed by each state or locality to estimate the number of thermostats coming off the wall each year (as is also required in the SERA/TRC approach, below).

b. Occupant Survey Responses and Analysis

California's mercury thermostat law requires that thermostat manufacturers estimate the number of mercury thermostats available for collection, and provide results to the CA Department of Toxic Substances Control (DTSC). In the fall of 2009, Skumatz Economic Research Associates (SERA) conducted a pilot study on behalf of TRC to demonstrate an approach for possibly determining that number. SERA used an online occupant survey to determine the number, age, and type of thermostats in place (and potentially available for removal) in both residential and commercial buildings, as well as those removed.[35] The survey results were validated with 30 on-site visits conducted in the San Francisco Bay Area. (These validation visits can be used to collect data for both Step 1 and Step 2.) Based on data from the more than 800 survey responses received, SERA developed a statistical model of expected thermostat removal patterns for buildings of different ages and types. This model was then used to assess annual and projected thermostat removals. The Skumatz Economic Research Associates (SERA), entitled "*Mercury-Containing Thermostats: Estimating Inventory and Flow from Existing Residential & Commercial Buildings"*, estimated that 19.8 million thermostats are in place in California businesses and residences. The weighted average age of thermostats in place is about 12.5 years. The survey determined that between 22% and 46% of thermostats currently in place in commercial buildings in California contained mercury, and between 27% and 47% of residential thermostats in place contained

[35] A "validation" survey (30 on-site visits in the San Francisco Bay Area) was also conducted to provide feedback on the accuracy of collecting data in this manner. Validation visits of this type can be used to collect data for both Step 1 and Step 2.

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mercury. The percent of thermostats in place that were digital was 54% in CA businesses, and 53% in CA residences.[36]

c. Sales data

For those unable to undertake one of the other two location-specific approaches owing to resource constraints, an alternative approach is to make computations using data collected on the number of thermostats sold for replacement, and assume that all thermostats being replaced will be either disposed of or recycled. The steps and necessary assumptions are detailed below.

Nationwide thermostat replacement sales numbers are provided in a 2003 report,[37] *North American HVAC Thermostat Markets*, by Frost & Sullivan[38]. The study provides detailed information on the number of thermostat units sold in North America for residential and commercial markets. The report provides a breakdown (by sales revenue) of the percentage of units sold for new construction and replacement markets. The difficulty of applying this report is that it provides an estimate of the replacement market, but not the share of the equipment being taken out contains mercury (see options for Step 2 below).

Applying the replacement percentages to the unit sales data produces an estimate of replacement sales for thermostats for North America. The U.S. market comprises 90% of the North American market. In a 2010 report entitled "*Measuring Performance of Mercury Thermostat Collection Programs: Approaches and Analysis* ", the Product Stewardship Institute (PSI) scaled these national estimates to the Commonwealth of Massachusetts.

d. Contractor Surveys as a Source

The PSI study "*Measuring Performance of Mercury Thermostat Collection Programs: Approaches and Analysis* " (2010), also tested the feasibility of gathering data on thermostat replacements and mercury content based on surveys with contractors. They partnered with two industry associations in an attempt to achieve high response rates, but in a nationwide survey, received no surveys from a number of states, and no more than 10 from any except one state. More information about this study is provided below under Step 2.

[36] Given that digital thermostats are 100% non-mercury, the "high end" of the ranges reported in the previous sentence are computed assuming all of the non-digital models are mercury.

[37] These reports are updated periodically and must be purchased from Frost & Sullivan. The 2003 report was the latest report available to government agencies.

[38] Frost & Sullivan publishes a periodic market description of the North American thermostat market. The data and estimates in the report are derived from surveys and interviews from the market participants, which are cross-verified where possible by interviewing other market participants in the industry, as well as end users and customers. The primary data are also evaluated against secondary data sources available publicly and in the company's databases. Market forecasts are derived using an expert opinion consensus model. Given the cost (approximately $5,000) and the emphasis on market descriptions and challenges, the document is primarily used by industry participants. For more information on the 2006 Frost & Sullivan report, see http://www.frost.com/prod/servlet/report-brochure.pag?id=N063-01-00-00-00.

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Step 2 –Estimating the Percentage of Thermostats that Contain Mercury

Three main methods have also been used for assessing Step 2:

- On-site expert inspection of the share of installed thermostats (in general or by "type") that contain mercury (e.g., SERA/NEMA and King County).
  Occupant survey / reports (e.g., Skumatz / NEMA[39] report), and
- Contractor surveys.

The strengths and weaknesses of these approaches for "Step 2" are summarized in Figure A.2 below.

Figure A.2: Options for Estimating the Percentage of Thermostats Replaced that Contain Mercury

Option	Strengths	Weaknesses
On-site inspection	• If conducting Step 2 using this method, data for Step 1 can be collected at the same time. • Same pros and cons as Table 2.	• Same pros and cons as Table 2 • Requires qualified staff able to remove covers and inspect units
Occupant survey	• If conducting Step 2 using this method, data for Step 1 can be collected at the same time. • Same pros and cons as Table 2.	• Same pros and cons as Table 2 • Although mercury content is clear for some thermostat types (e.g. digital), it is difficult for residents to be certain if some types of thermostats contain mercury (e.g. round types, etc.) unless covers are removed.
Contractor survey	• Straightforward estimates of share of mercury-containing thermostats can be computed from data collected on total thermostats removed and number containing mercury.	• Must identify suitable "population" list, design sample, and check / control for non-response bias • Generally does not provide data to help estimate how the share of thermostats that contain mercury changes over time[40] .

a. On-Site Inspection and Occupant Survey

If either the on-site inspection or the occupant survey approach is used for Step 1, data can also be obtained for Step 2 at the same time to determine whether or not a thermostat contains mercury. If on-site inspection is used, high quality data will likely be obtained because inspectors are skilled at identifying thermostats that contain mercury. However, as mentioned above, this approach is resource intensive. If the occupant survey approach is used, the data will be less reliable since it relies on occupants, not professional contractors, to identify whether the thermostat contains mercury.[41] However, this approach is less resource intensive than on-site inspection. Results from both are subject

[39] This study also used some on-site validation to examine the share of each thermostat "type" remaining in place (for future removal) contained mercury; however, these inspected whether the remaining thermostats

[40] One can gather data to address this issue or surveys can be performed periodically to update the data (for goal-setting into the future).

[41] Some have suggested that occupants be asked to open the thermostat to determine if it has a mercury ampoule. However, this approach is not recommended for safety reasons.

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to the issue of non-response bias, if patterns of homes or businesses deny access to the building or refuse to return the survey.

b. Contractor Surveys

Regardless of the approach used in Step 1, a heating and cooling contractor survey can provide data on the number of thermostats removed by the contractors from walls over a specific period of time and how many contain mercury. If either the on-site inspection or occupant approach is used, the contractor survey can still be used to corroborate data about the percentage of thermostats that contain mercury. If either of those two approaches is *not* used, a well-designed and executed contractor survey could theoretically provide the necessary information to calculate a thermostat collection rate. Two low-cost pilot tests were conducted, and summarized in PSI study "*Measuring Performance of Mercury Thermostat Collection Programs: Approaches and Analysis*", (2010).[42]

In the spring of 2010, PSI enlisted the help of two associations of heating and cooling contractors – the Air Conditioning Contractors of America (ACCA) and the Plumbing, Heating, and Cooling Contractors (PHCC) – to gather information on the percentage of thermostats removed that contain mercury. PSI implemented two surveys: (1) a national survey of ACCA and PHCC members and (2) a statewide survey of contractors in Massachusetts. They tried on-line surveys to a membership list of 3000 contractors, and received 160 responses (15 states had no responses, 10 or more responses were received from 6 states). The responses were non-random, and compromised the analysis, but the pilot was useful in pointing out that gathering data from contractors was not, as hoped, quick, cheap, and reliable. The research was useful, and the report works to identify some possible strategies to improve the approach; however, strategies to achieve results inexpensively were not uncovered.

A second pilot, conducted totally in Massachusetts, involved interviews with 65 (of the 81) ACCA member companies. They were provided a tracking form to provide data on the percent of thermostats they removed / received contained mercury. Each firm was called at least 3 times over a two-month period, to remind them about tracking. An analysis of the 27 firms responding, which was too small (and not complete / random enough) to provide meaningful analysis. Again, suggestions were made to improve the approach (more follow-up calls, etc.); however, the search for a low-cost, easy approach using contractors was shown to be less easy than expected / hoped.[43]

[42] The author of this Illinois study (Skumatz) also served as an advisor on this PSI research.
[43] The author of this study for Illinois / NRDC was an advisor/ reviewer to the PSI study.

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Appendix B: Response Rate Comparisons

Figures B.1 and B.2 compare the response rates for single family households and commercial businesses,[44] by county, to the purchased population. Note that responses from Cook County were divided by 10, in order to keep the figures from other counties on a readable scale. Although there are differences (DuPage County is one example), there did not seem to be significant enough in the way of systematic differences to warrant complex re-weighting by county.

[44] Responses from multifamily are not graphed; there were too few responses to spread across 100 counties.

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Figure B.1: Graph of Single Family Response Rates by County Compared to Purchased Population

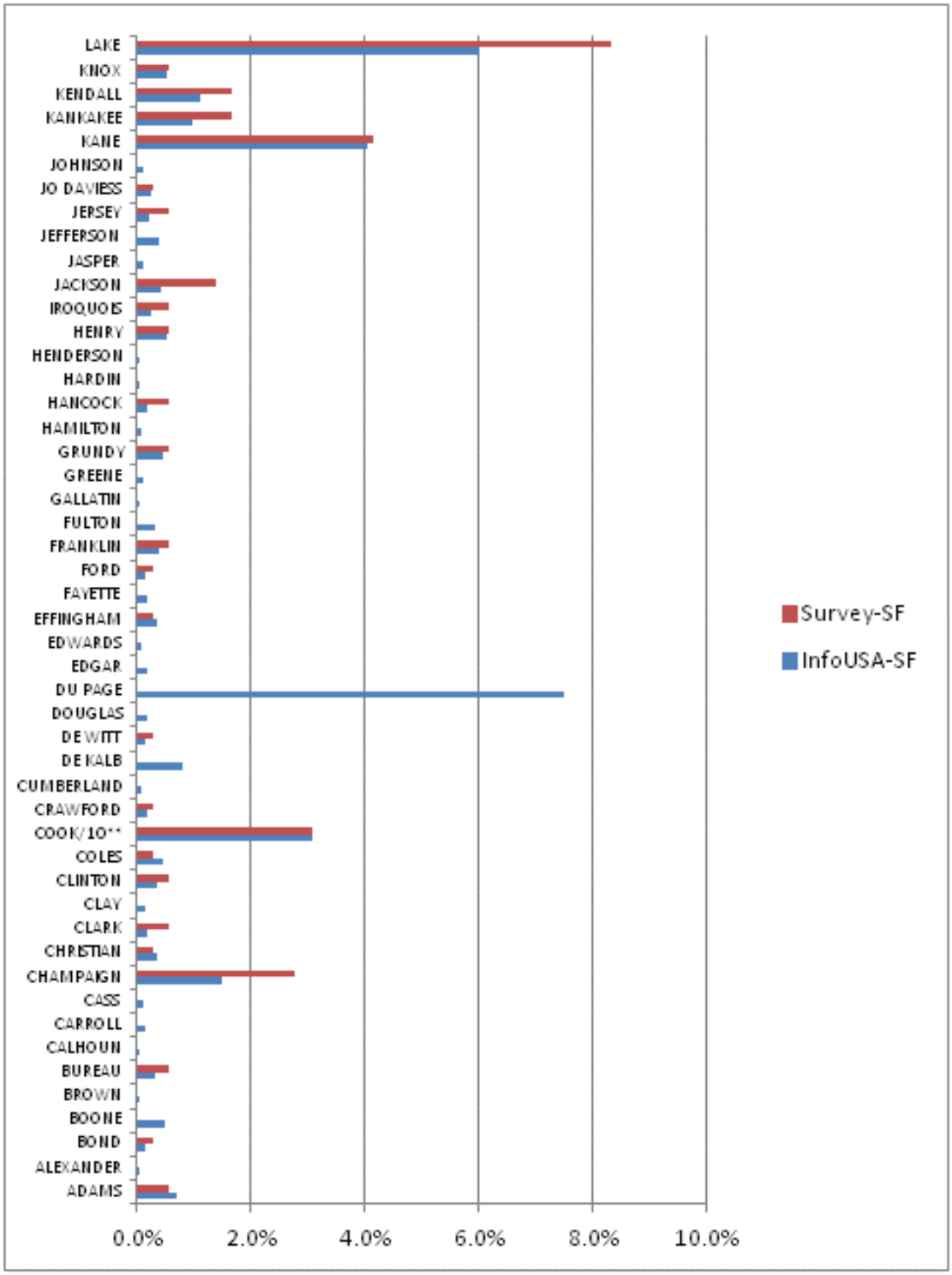

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Figure B.1: Graph of Single Family Response Rates by County Compared to Purchased Population, continued

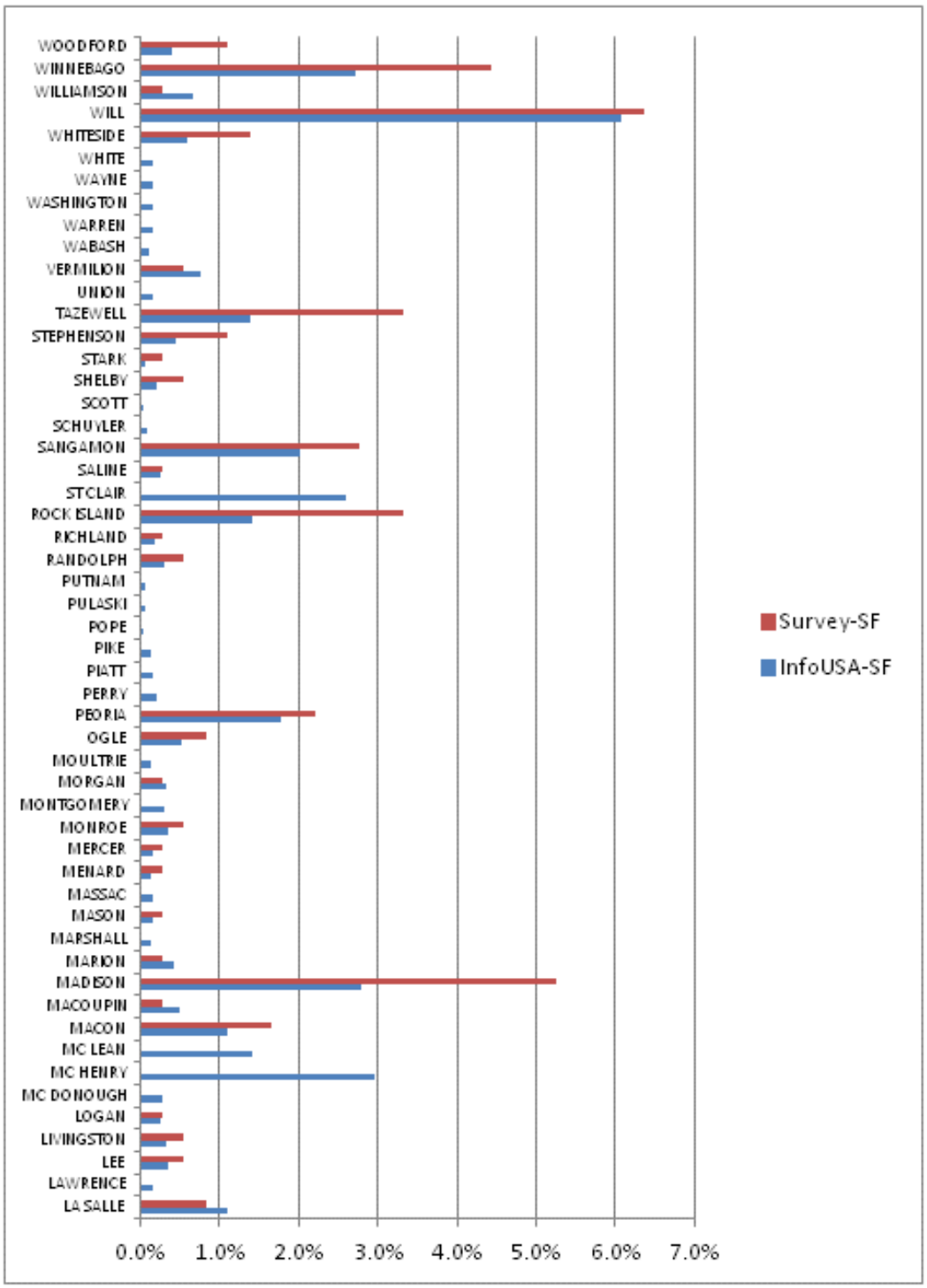

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Figure B.2: Graph of Commercial Response Rates by County Compared to Purchased Population

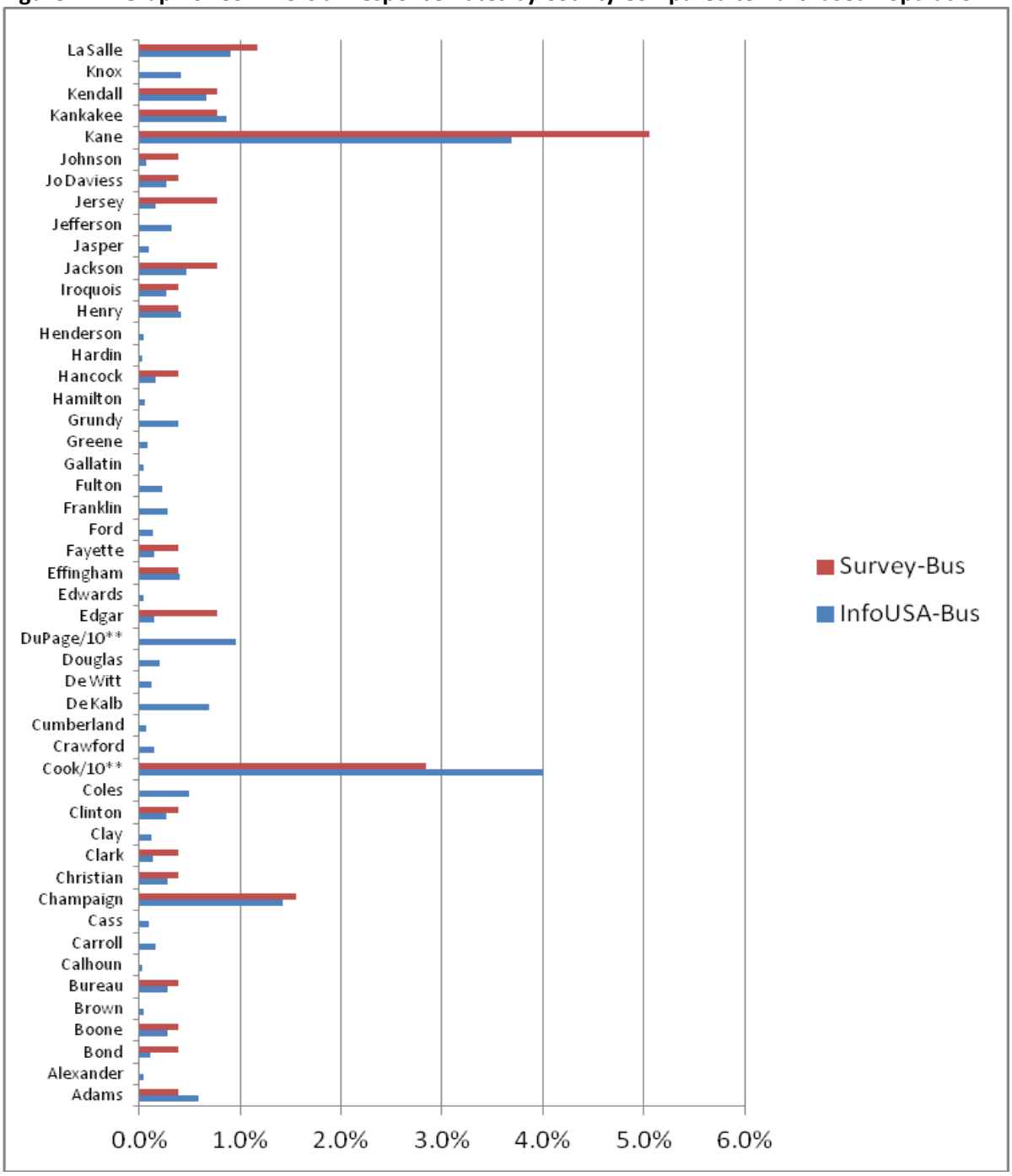

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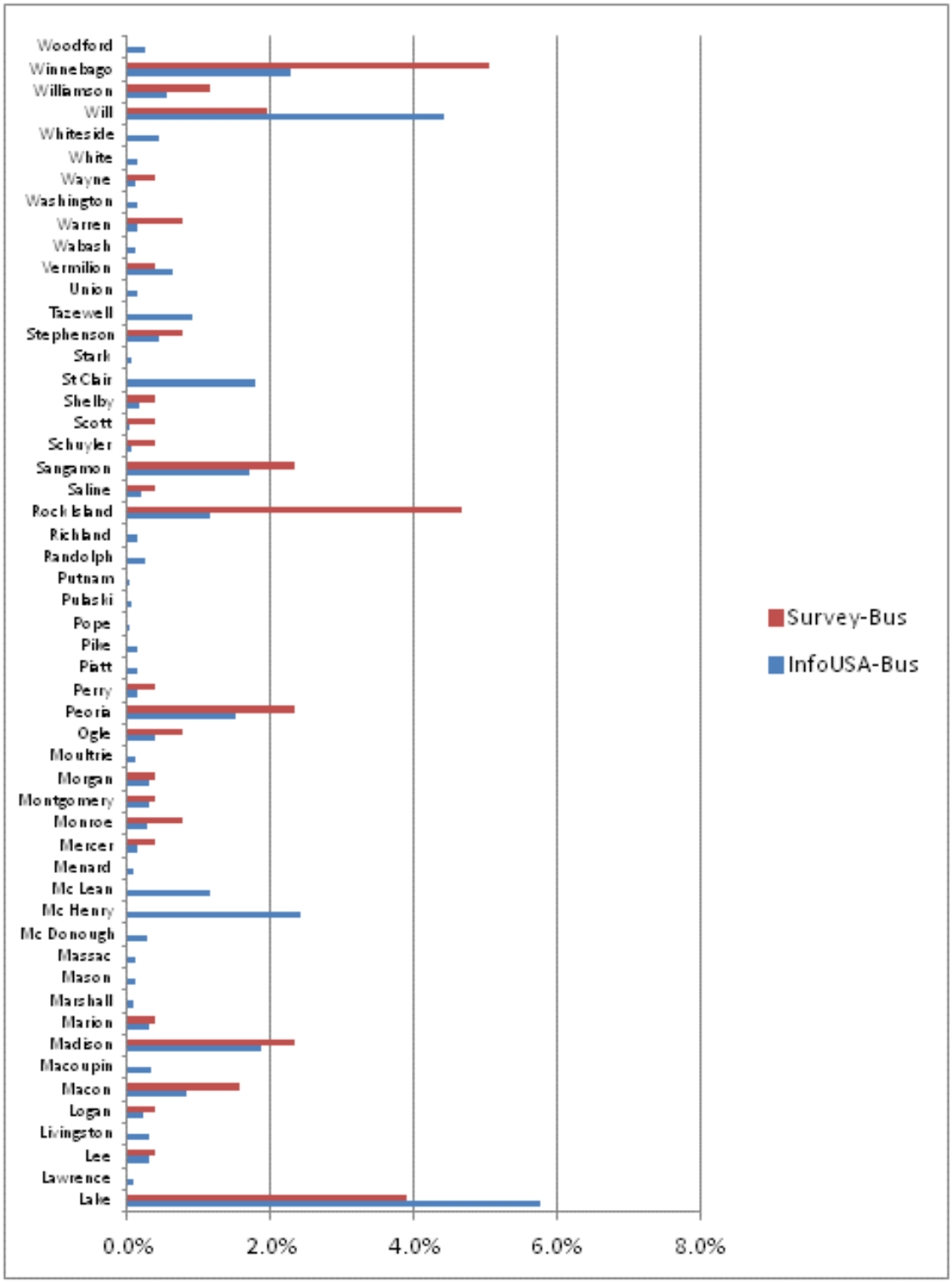
Figure B.2: Graph of Commercial Response Rates by County Compared to Purchased Population, continued



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Appendix C: Detailed Validation Results

Figure C.1: Number and Percent of Mercury-Containing Thermostats from On-site Inspection

On site Validation	Commercial- on site	Residential - on site
SQUARE		
% with Mercury	70%	100%
Number Found	30	4
Contained Mercury	21	4
ROUND		
% with Mercury	95%	100%
Number Found	21	7
Contained Mercury	20	7
DIGITAL		
% with Mercury	0%	0%
Number Found	133	3
Contained Mercury	0	0
SNAP		
% with Mercury	3%	NA
Number Found	33	0
Contained Mercury	1	0
LEVER/DIAL		
% with Mercury	9%	sample too small
Number Found	56	1
Contained Mercury	5	1

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Figure C.2: Validation Results on Total Count of Thermostats, Total and by Thermostat Type

Number of Thermostats identified by "type", all validations combined	Survey Reports (raw number); Res / com'l	Verified on-site or camera (raw number); Res / com'l
Square	5/51	8/34
Round	13/32	10/24
Digital	22/104	21/164
Snap	0/81	0/33
Lever/Dial not in photo	0/50	1/57
Total Residential	40	40
Total Commercial	318	312
Grand Total	358	352

Figure C.3: Re-computation of Total Mercury Thermostats based on Commercial Thermostat Mis-Identification from Validation

Number of Thermostats identified by "type", all validations combined	Survey total based on Figure 2.8	Revised incorporating commercial thermostat type mis-identifications
Total Mercury-containing thermostats	1,910	1,790 (6% fewer)

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Appendix D: Survey Instrument

Illinois Recycling/Hard-to-recycle Survey

A. Introduction

Please help improve recycling programs in the State of Illinois. Over the next year, the State is tasked with researching some specific recycling options, and we are investigating ways to improve recycling programs including programs for several hard-to-recycle items. The results of this study will be used to improve the design of recycling and disposal programs across the State. Your building/home is one of a small sample selected to "stand in" for all the buildings/homes in the State of Illinois, so your help on this survey is VERY important. Your response will enter you into a drawing for one of six $100 gift certificates to Best Buy or Target, and a grand prize of a Kindle Fire HD tablet. To be eligible, you'll need to answer a couple key questions. Your individual answers will be kept confidential and will not be used to identify you or your building in any way. You may also sign up to request a copy of the results of the survey. We really need your help!

B. Building 1

Please think about the address that was included on the postcard that directed you to this survey, or the address of the company to which the email was directed.

1. How did you hear about this survey / what directed you to this survey? (color of postcard)

- Pink postcard (house)
- Yellow postcard (apartment/multifamily)
- Orange postcard (small business)
- Purple postcard (medium business)
- Green postcard (large business)
- Blue postcard (large business)
- Email (please answer for your BUSINESS facility)
- Other
- Not sure
- Other (please specify)

2. What is your 5-digit zip code? (not for identification, but to check representativeness of results)

3. In which county in the State is this building/home located?

4. Is this address a... (please check best answer) (type of building)

C. Commercial Recycling

The preferred respondent would know about the business's recycling program and about wall thermostats. For small businesses, it may be the owner, manager, or (long-term or other) employee; for larger businesses, the facilities manager, maintenance department, or others may be most suited. If these people are not available (or unlikely to answer) please answer the survey for us yourself to the best of your ability!

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1. What is your job title and years at the location?
   - Your job title?
   - How many years have you worked at the location?

2. Do you have a recycling program at this location?
   - Yes, for employees
   - Yes, for customers
   - Yes, for both
   - No
   - Don't know
   - Other (please specify)

3. If yes, how does the program work? (check all that apply)
   - No program
   - We contract with our trash hauler to collect
   - We contract with a recycling company to collect
   - The city/county collects
   - The property management company handles the program
   - Don't know
   - Other (please specify)

4. Is the program mandatory?
   - Yes, I think all commercial properties in my area are required to recycle
   - No
   - Don't know
   - If no or don't know, why does your business recycle?

5. Please select which materials are recycled/diverted at your location? (check all that apply)
   - Office paper
   - Magazines
   - Cardboard
   - Cereal box-type packaging
   - Plastic containers
   - Glass
   - Aluminum
   - Tin
   - Plastic bags
   - Plastic packaging
   - Food waste
   - Yard waste
   - Electronics
   - Wood waste
   - Other (please specify)

6. What recycling programs, if any, would you like to see the State focus on?

D. Thermostats

We are interested in learning more about thermostat disposal and replacement in Illinois. Responses to the following set of questions will help the State improve possible thermostat recycling programs.

1. Approximately when was this building built? This information is very important – please make your best estimate.

2. Are there wall thermostats to control the heating and/or cooling temperatures in your building?
   - Yes
   - No
   - Don’t know

3. Number of thermostats (This question is very important; we appreciate a quick walk-around wall count)
   - Approximately how many wall thermostats are located in your space in the building?

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- How many are still operating?

4. To the best of your knowledge, about what year were (all or most of) the wall thermostat(s) installed in your building?
   - What years were others installed? Please provide the best estimate(s) you can.

5. Do you believe the wall thermostats date from when the building was built (original equipment)?
   - Yes, all of them are (or seem) original
   - No, none are (or seem) original
   - Not all, but more than half seem original
   - Some, but fewer than half seem original
   - There are no wall thermostats
   - Don't know

6. About what year did your firm move into this space or building?

7. Have these wall thermostats been in place since before your firm moved in?
   - No changes all
   - wall thermostats here since before we moved in
   - All have been replaced since we moved in
   - Not all, but more than half replaced since we moved in
   - Some, but fewer than half replaced since we moved in
   - There are no wall thermostats
   - Don't know

IMPORTANT: About how many in place since before you moved in? (please specify)

E. Thermostat Pictures

We are showing a few pictures of general "classes" of thermostat types below (be sure you can see the round & snap types on the right). We'll be asking about which type are in your building...

1.Which of the above picture(s) best matches the wall thermostat(s) CURRENTLY in your space in the building? Brand does NOT matter. List the approximate NUMBER of each type in your space in the building. (This question is VERY important for our study and MUST be answered to be eligible for the prize. Please make sure to provide your best estimates for all columns).

Type	Number currently in building	Number still working	Estimated year they were installed
Square type 1 or 2			
Round type			
Digital electronic type			
Snap type			
Not in photo but other digital/electronic			
Not in photo but other thermostat with lever or dial to raise/lower temperature			
Other thermostat type			

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2. Looking at the same pictures, can you report how many of each type have been removed? This is also a very important question please try your best. (Again, brand does NOT matter.)

Type	Number that used to be in building but have been removed	Year they were removed (best estimate)	Approximate year they were originally installed
Square type 1 or 2			
Round type			
Digital electronic type			
Snap type			
Not in photo but other digital/electronic			
Not in photo but other thermostat with lever or dial to raise/lower temperature			
Other thermostat type			

If additional thermostats have been removed, please describe number, removal date, and age here (or if some of one type were removed at two different times)

3. Approximately how many total thermostats were replaced/removed?

F. Thermostats 2

1. To the best of your knowledge, why were the wall thermostats removed and/or replaced? (check all that apply)

- No replacement
- Expansion of building space
- Broke/stopped functioning
- Wanted to install programmable type
- Utility replaced / utility program
- Conversion of space for new use(s)
- Renovations or replacement of heating, cooling, or electrical system
- Don't know
- Other (please specify)

2. Was the heating / cooling system replaced or updated without removing existing wall thermostats?

- No changes
- Yes, sure
- Yes, pretty sure
- No
- Don't know

3. Do you know what happened to the removed wall thermostats?

- No replacement
- Contractor disposed – Don't know what he did with them
- Contractor disposed and said they were going to special recycling or other facility for proper disposal
- They were disposed of in the trash
- They were delivered to a recycling facility/program/hazardous material facility
- They were used in other locations in building or another building
- We still have (some or all of) the old ones in storage
- Don't know
- Other (please specify)

4. About how many removed or unused thermostats do you have awaiting discarding or recycling?

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G. Building ownership, size, activities

Please think about the address that was included on the postcard that directed you to this survey or the business to which the email was delivered.

1. Are there multiple businesses in this building?
   - Yes
   - No
   - Not sure
   - Other, specify

2. About how many businesses are in this building?
   - One Only -our firm
   - 2
   - 3-5
   - 6-10
   - More than 10
   - Other (please specify)

3. About how much of the building's space does your business occupy (make your best guess)? Put 100% if yours is the only firm.
   - <10%
   - 10-19%
   - 20-29%
   - 30-39%
   - 40-49%
   - 50-59%
   - 60-69%
   - 70-79%
   - 80-89%
   - 90-99%
   - 100% (only firm)
   - Don't know
   - Other (please specify)

4. Do you own or rent the space you occupy?
   - Own or buying
   - Long term lease (more than 3 years)
   - Short term lease / rent (3 or fewer years)
   - Other (please specify)

5. Which category best describes...

	Your business – locally within this building	Your business – at head-quarters located elsewhere	Federal, state, county, or city government	A property management company
...the organization that manages the building?				
...who makes decisions about building equipment, heating systems, thermostats, etc.?				

6. What is your best estimate of the size range for YOUR SPACE and for this BUILDING? (separate columns)
   - 1,000 sq ft or less
   - 1001-5,000 sq ft
   - 5,001-10,000
   - 10,001- 20,000
   - 20,001-50,000
   - 50,001-100,000
   - 100,000- 300,000
   - 300,001 sq ft or more
   - Unsure

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7. What is the best range for the number of employees in this building for YOUR FIRM and the WHOLE BUILDING (including yourself)? (separate columns)

- 1-2
- 3-5
- 6-9
- 10-19
- 20-49
- 50-99
- 100-249
- 250-499
- 500 or more Unsure

H. Heating Systems & Computers

1. Does this building have central heating and/or central air conditioning? (check all that apply)
   - Yes, central heating system with thermostat(s)
   - Yes, central cooling system with thermostat(s)
   - No central heating or cooling system controlled by thermostat(s)
   - Not sure
   - Other (please specify)

2. We have a couple of questions about electronics / computers and their disposal / recycling...
   - About how many computers are in use in your firm?
   - About how many computers are broken / stored?

3. What is your computer replacement policy? (check all that apply)
   - Replace only when they are broken
   - Replace many / most / all at one time (specify how long between replacements)
   - Dispose of the computers in trash
   - Recycle the computers at a facility
   - Recycle the computers through a firm
   - Donate the computers
   - Reuse computers elsewhere
   - Other (specify)
   - Computer replacement cycle in months or years; Other (please specify)

I. Commercial Ending

1. If you are satisfied with your answers, please click on the "Done" button below.

J. Residential Recycling

1. Do you have recycling collection at your house/apartment?
   - Yes-it is included in our trash bill
   - Yes-we signup and pay extra for recycling
   - No-we do not have recycling
   - Other (please specify)

2. Who collects your recycling?
   - Our trash hauler
   - A recycling company
   - The city/county collects the recycling
   - Not sure
   - Other (please specify)

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3. How is recycling collected? (check all that apply)

- We do not have recycling collection
- We take recyclables to a dropoff location
- We put all our materials in one container collected at our house
- We separate into two containers (one for paper, one for containers)
- We separate into more than two containers
- Don't know
- Other?

4. If you have recycling collection, how often is it collected?

- Twice a week
- Weekly
- Every other week
- Once a month
- No collection
- Don't know
- Other (please specify)

5. If you have a recycling program, why do you/your family choose to recycle? (please select all that apply)

- It is mandatory
- We pay for it so we might as well recycle
- It helps save money on our trash bill
- My kids want to
- All of my neighbors are doing it
- It saves natural resources
- It saves space in the landfill
- It can reduce greenhouse gases
- It is easy and convenient
- It is good for our economy
- We do not recycle
- Other (please specify)

6. Do you have organics/yard waste collection?

- Yes, we have yard waste collection year round
- Yes, we have yard waste and food waste collection year round
- Yes, we have yard waste and food waste collection seasonally
- Yes, we have yard waste collection seasonally
- Yes, we have food waste collected year round
- No
- If yes, does it cost extra to have this service?
- Other-please specify

7. What changes, if any, would you like to see the State undertake to improve recycling?

K. Residential Thermostats

Illinois is very interested in learning about disposal and replacement of wall thermostats. Responses to the following set of questions will help the State better plan potential thermostat recycling programs.

1. Approximately when was this home/building built? This information is very important – please make your best estimate.

2. Are there wall thermostats to control the heating and/or cooling temperatures inside your residence?

- Yes
- No
- Don’t know
- Other (please specify)

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3. If you live in an apartment- Are there wall thermostats to control the heating and/or cooling temperatures in "common spaces" (entryway for apartment building, etc.)

- Yes
- No
- Don't know
- Other (please specify)

4. Number of thermostats-This question is important. Please take a quick walk around to see...

- Approximately how many wall thermostats are located in your home/residence?
- How many are still operating?

5. To the best of your knowledge, what year were the wall thermostat(s) installed in your home?

- If multiple years, put additional years here. Please provide the best estimates you can.

6. Do you believe the wall thermostats date from when the home was built (original equipment)?

- Yes all are (or seem) original
- Some are (or seem) original
- None are (or seem) original
- Don't know
- Other (please specify)

7. Approximately when did your family move into this home?

8. Have these wall thermostats been in place since before your family moved in?

- Yes all of them
- Some of them
- None of them all replaced
- Don't know
- Other (please specify)

L. Residential Thermostat Pictures

We will be asking questions about the following thermostat "types" (be sure to notice the round and snap types on the right)...

1. Which of the above picture(s) best matches the wall thermostat(s) CURRENTLY in your space in the building? Brand does NOT matter. List the approximate NUMBER of each type in your space in the building. (This question is VERY important for our study. Please make sure to provide your best estimates for the columns)

Type	Number currently in home (or unit)	Number still working	Estimated year they were installed
Square type 1 or 2			
Round type			
Digital electronic type			
Snap type			
Not in photo but other digital/electronic			

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Type	Number currently in home (or unit)	Number still working	Estimated year they were installed
Not in photo but other thermostat with lever or dial to raise/lower temperature			
Other thermostat type			

2. Looking at the same pictures, can you report how many of each type have been removed? This is also a very important question please try your best. (Again, brand does NOT matter.)

Type	Number that used to be in home (or unit) but have been removed	Year they were removed (best estimate)	Approximate year they were originally installed
Square type 1 or 2			
Round type			
Digital electronic type			
Snap type			
Not in photo but other digital/electronic			
Not in photo but other thermostat with lever or dial to raise/lower temperature			
Other thermostat type			

If additional thermostats have been removed, please describe number, removal date, and age here (or if some of one type were removed at two different times)

M. Residential Thermostats 2

1. Approximately how many TOTAL thermostats were replaced/removed?
   - Clarify larger counts; Other issues (please specify)

N. Residential Thermostats

1. To the best of your knowledge, why were the wall thermostats removed and/or replaced? (check all that apply)
   - No replacement
   - Expansion of the home
   - Renovations or replacement of heating, cooling, or electrical system
   - Thermostats not working/stopped functioning
   - Wanted to install a programmable type
   - A utility company program
   - Don't know
   - Other (please specify)

2. Was the heating / cooling system replaced without removing existing wall thermostats?
   - No changes to heating/cooling system
   - Heating/cooling system changed without removing wall thermostats
   - Heating/cooling system changed WITH change /replacement of thermostats
   - No thermostats
   - Don't know
   - Other (please specify)

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3. Who made the decision to remove / replace the wall thermostats and/or heating system?

- No replacement
- My family
- Landlord
- Home owner association
- Property manager
- Other (please specify)

4. Do you know what happened to the removed wall thermostats? (check all that apply)

- No replacement
- Contractor disposed – Don't know what he did with them
- Contractor disposed and said they were going to special recycling or other facility for proper disposal
- They were disposed of in the trash
- They were delivered to a recycling facility/program/hazardous material facility
- We still have (some or all of) the old ones in storage
- They were used in other locations in home / another home
- Don't know
- Other (please specify)

5. About how many removed or unused thermostats do you have awaiting discarding or recycling?

6. Does your home have central heating or central air conditioning? (check all that apply)

O. About the Home

These last few questions are needed to help us analyze the data in the aggregate. They will NOT be used to identify you.

1. If you are in a multifamily building: Approximately how many apartment units are in this building?

- Yes, central heating and air conditioning controlled jointly by a thermostat
- Yes, central air conditioning with a thermostat (separate from window units)
- Yes, central heating system with a thermostat (separate from baseboard heaters)
- No, we have neither
- Not sure
- If other, please specify

2. Do you own or rent your home/apartment?

- Own or buying
- Rent / lease
- Other (please specify)

3. About how large, in square feet, is your residence?(Please DO NOT include garage or unheated spaces like crawl spaces)

4. How many...

- Bedrooms are in your residence
- Bathrooms are in your residence

5. Including yourself, how many persons normally live in this residence on a fulltime basis?

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6. What is the highest grade of schooling completed by the head of household?

- Grade school
- Some high school
- High school graduate
- Some college
- Business / technical school
- College graduate
- Some graduate school
- Graduate degree
- Other (please specify)

P. Thanks!

Thanks you very much for taking the time to complete our survey. Both your time and input are invaluable to us.

1. Are you planning any remodels or changes that will remove thermostats?

- No
- Yes, in 2013
- Yes, in 2014-2015
- Yes, other year
- Not sure

2. Were you aware that there could be mercury in older, non-digital thermostats?

- Yes
- No
- Not sure

3. What do you typically do with your home's old compact fluorescent light bulbs (CFLs)?

- We don't use CFLs, we use traditional bulbs
- We don't use CFLs, we use newer bulb types (LEDs)
- Throw directly in the trash
- Put in a bag or other container and put in the trash
- Bring to a recycling facility to dispose
- Bring to a landfill / transfer station to dispose
- Bring to a retailer to dispose
- Not sure
- Other (please specify)

4. How do you normally dispose of your household alkaline batteries (AA, AAA, etc. type batteries)?

- Throw in trash
- Put in recycling bin
- Bring to hazardous waste center
- Bring to recycling center
- Not sure
- Other (please specify)

1. PRIZE: Would you like to be entered into the drawing for one of six $100 gift certificates or a Kindle Fire HD 7" tablet?

- Yes
- No
- IF YES, please provide your name, phone number, business address / address, and email.

1. Please enter your contact information to be eligible for the prize.

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2. If you would like to receive a summary of the results of this survey, please provide an email address below.

- Name:
- Business / Home Address:
- City
- Phone:
- Email:

3. If you are willing to provide your address, we can link to a database that gives a good estimate of the date your building / home was built. If you were uncertain about construction date in our questions, this address information would be very helpful. It will not be used to identify you. Please enter address / city / zip if you are willing or if you were uncertain of this date.

Please click next.

1.Would you be willing to be contacted with any follow up questions about your thermostats?

- No, please do not contact me
- Yes, you may contact me
- If yes, please provide a way to contact you.

Q. Thanks!

1. If you have any other comments or questions about the survey or project please let us know:
THANK YOU for completing our survey!

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